MECHANICAL ENGINEERING

INCLUDING THE ENGINEERING INDEX

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APRIL 1926

THE MONTHLY JOURNAL PUBLISHED BY THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

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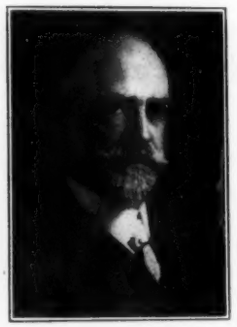
R. E. Hall

C. E. Skinner



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* * * * *

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* * * * *

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* * * * *

W. F. Durand is a scientist and consultant of international reputation in the field of mechanical engineering. He has taken an active part in the development of aeronautics and marine engineering, and last year was appointed by President Coolidge to the President's Aircraft Board on which he served as secretary. He is a past-president of the A.S.M.E. and since 1909 has been a member of the Board of Consulting Engineers for the city of Los Angeles in connection with the development of hydroelectric power in that city. In 1918 and 1919 he was scientist attaché at the American Embassy in Paris, and was a member of the Inter-Allied Committee on Inventions.

* * * * *

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* * * * *

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* * * * *

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A.S.M.E. TRANSCONTINENTAL TOUR

The transcontinental tour plans in connection with the coming Spring Meeting at San Francisco, June 28 to July 1, have been perfected and changes made to include more time at many interesting points. This thirty-day tour in a de luxe special train will cover eight thousand miles and pass through the most interesting scenic regions of the United States and Canada. Over 325 have signified their intention of taking it. For detailed itinerary see the A.S.M.E. NEWS for March 7, 1926.

MECHANICAL ENGINEERING

Volume 48 April, 1926 No. 4

Technical Progress in Aeronautics

The Trend in Airplane Construction—Increasing Use of Metal in Fuselage and Wing Structures—Lighter, More Rigid, and More Powerful Engines—Metal Propellers—Improvements in Navigating Instruments—Roll Reduction Through Braking, Etc.

By EDWIN E. ALDRIN,[1] DAYTON, OHIO

AT A TIME when so much discussion and investigation is being made of aeronautics in general, some useful purpose may be served by taking account of stock of the progress made from the technical standpoint. In a paper of this scope it will be impossible to give full credit to all responsible for the particular development, for all individuals actively engaged in aeronautics have more or less responsibility with some development.

In general, a remarkable advance in aeronautics has occurred year after year. Of late years, however, although the greatest amount of credit must be given airplane and engine designers for their untiring work in refining the conventional article, the final performances obtained have nevertheless been largely due to the coöperation of flying, maintenance, mechanical, and inspection personnel. Development, as the majority in the United States know it, dates from our entry in the World War. Progress has since then been of two periods: post-war, digesting the practical and theoretical data and experience, to form a firm scientific foundation; and thereafter trying pure American ideas, design, and building, until we stand ready to "go into production" on a safe and sane program, commercial and otherwise. We have now reached the stage where design in aviation can be considered an economical procedure.

Airplanes

The trend of airplane construction may be summed up as a greater refinement and a general reduction of exposed structure, accompanied by a larger span. (See Fig. 1.) A "split" landing gear or rather an individual structure of support for each wheel is common practice. Biplanes continue to predominate chiefly because monoplanes seem to have given excess trouble by fluttering or in torsional deflection. A tendency toward monoplanes is developing for heavier-duty airplanes, in which a more rigid internal trussing is practicable. Pursuit airplanes have become essentially one and one-half plane machines, as a compromise, to avoid flutter and still retain excellent visibility. So that, if it is permissible to generalize, biplanes may be said to predominate in the case of observation and racing airplanes and seaplanes, but seem to be losing ground elsewhere. We find the biplanes having single-bay, long-span construction.

Effect of Large Fuselages on Performance

With increase in sizes of fuselages for purposes of transport, an interesting complication has arisen. At McCook Field in the case of a military transport it was found that gearing down a propeller from direct drive to a ratio of 2:1 resulted in an increase of 10 miles per hour in high speed and 340 feet per minute climb at the ground. Whether this is due to propeller-body interference or to a greater propeller efficiency at slower speeds, or a combination of the two, is not definite. It would seem that a slower speed and therefore larger propeller diameter would automatically place the most efficient part of the propeller well away so as to prevent any possible interference to the slipstream by the nose of the body, resulting in what some term greater *propulsive efficiency*.

Maneuverability

A study of the maneuverability chart devised by Kerber and shown in Fig. 2 will give a very good idea of airplanes and their flying

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Contributed by the Aeronautic Division and presented at the Annual Meeting, New York, November 30 to December 4, 1925, of The American Society of Mechanical Engineers.

Fig. 1 The Douglas C-1 Cargo-Type Airplane

(The single-bay, long-span wings and "split" landing gear represent the present tendency. This plane will carry 8 persons and baggage by means of one Liberty engine.)

TABLE 1 DATA ON A T-3 L.W.F. MILITARY TRANSPORT

	Direct drive	Epicyclic gear	2:1 Spur reduction gear
Diameter of propeller, ft.	10.5	14	15
High speed at ground, m.p.h.	98.7	(1855 r.p.m.) 102.7	(1900 r.p.m.) 108.3
Absolute ceiling, ft.	(1625 r.p.m.) 10,300	(1600 r.p.m.) 12,650	(1595 r.p.m.) 11,400
Climb at ground, ft. per min.	280	550	618

qualities. In military airplanes, maneuverability is a quality much sought for, but for commercial and transport craft it is quite secondary. The factor shown furnishes a definite basis for designers to work upon, and therefore represents a forward step. Likewise it furnishes a basis for comparing airplanes of widely different characteristics. The maneuverability factor involves in a measure the

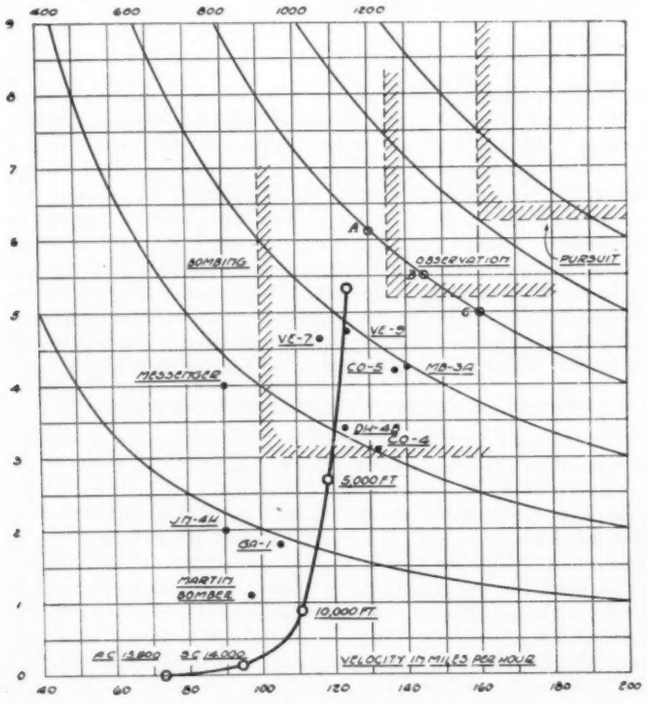

FIG. 2 MANEUVERABILITY CHART

(The maneuverability factor based on ability to execute a sharp turn quickly is plotted on the ordinates R/r, R being rate of climb, ft. per min., and r the minimum radius of steady turn in horizontal flight, ft. This serves to group distinctive classes of airplanes. The value for the commercial plane should be near that of the Martin bomber.)

question of excess power, which must necessarily be a minimum for economical work, this minimum being largely dictated by the landing fields for take-off and the mountains to be traversed. Consequently commercial machines might be placed directly beneath the bombers—that is, the same speed but a lower maneuverability factor. Reduction in maneuverability below a certain value would mean a lessening of safety in case of engine trouble, and especially so in multi-engined machines.

STRUCTURES

Hand in hand with the progress in performance and maneuverability in aircraft must necessarily advance the study of airplane structures. By means of static testing or proof loading the actual strength of the completed structure may be checked, be it fuselage, wing, tail surface, tail skid, landing gear, or a combination thereof. Continuous study and the accumulation of statistics in static testing have evolved a series of load factors for various conditions and parts for each type of military airplane. The cargo type in Table 2 represents the commercial airplane. Some of the factors given are very rigid, but it is realized it is better to have them and modify them only when a specific design might be improved thereby. This makes for progress with safety.

Conventional airplanes are no longer loaded to destruction. Doubtful or new combinations of structure or untried parts and materials are loaded usually to destruction, but sometimes tested only for certain readings of deflections under increments of load.

LANDING GEAR

It will be noticed that in Table 2 the ninth column gives the height of free drop for shock-absorbing units. These are values for use in testing the chassis in supporting the fully loaded airplane fuselage without wings. The height given is the final height reached after successive drops increasing from three to six inches each time. The tail of the fuselage is slung from a superstructure. The landing gear strikes a platform having an inclination of $9\frac{1}{2}$ deg. to the horizontal to simulate conditions occurring in a cross-wind landing. It is of interest in this connection to mention two tests on two types of landing gear attached to the CO-6 airplane. One was equipped with shock absorbers and the other was not, the structure for the latter being increased somewhat and large tires being used to take the increased shock. Both chassis passed the drop test successfully, and the balloon tires of the second were sufficient to absorb the entire shock of landing without the usual rubber shock absorbers.

FIG. 3 THE OLEO SHOCK-ABSORBING LANDING GEAR ON THE CO-4

(A tendency to "lean over" in sharp turns on the ground has been overcome by a cable limiting the movement.)

There is a decided tendency at present to simplify the landing gear by eliminating the old floating cross-axle and hinging the individual axle at the fuselage so that each wheel is attached in a separate unit. Although this is more complicated and is hard on the fuselage structure, it is necessary to avoid trouble in landing. The shock absorbers in many cases are brought up into the fuselage. The Oleo shock-absorbing apparatus (Fig. 3) has been successfully used on the CO-4 for more than a year, and it is quite probable that this will replace the prehistoric rubber shock absorber in commercial practice.

TABLE 2 DESIGN LOADS FOR MAJOR ASSEMBLIES

(Engineering Division Load Factors, April, 1925)

Designation	Type name	Load factor for: High incidence	Low incidence	Inverted flight	Landing condition	Ribs in medium incidence	Leading edge	Height of free drop for shock-absorbing units, in.	Ailerons and horizontal tail surfaces, lb. per sq. ft.	Vertical tail surfaces, lb. per sq. ft.
P	Single-seater pursuit	12.0	6.5	4.0	7	9.25	14	24	35	30
O	Two-seater observation	8.5	5.5	3.5	6	7.0	10	21	30	25
NO	Two-seater night observation	8.5	5.5	3.5	6	7.0	10	21	30	25
LB	Light bombardment	5.5	3.5	2.5	5	4.5	8	18	25	20
HB	Heavy bombardment	4.5	3.0	2.5	5	3.75	6	18	20	15
PT	Primary training	8.0	5.5	3.5	7	6.75	14	24	35	30
AT	Advanced training	8.0	5.5	3.5	7	6.75	14	24	35	30
C	Cargo	5.5	3.5	2.5	5	4.5	8	18	25	20

NOTE: Seaplanes shall be designed for the same load factors as land airplanes of the same function, in all loading conditions common to both types. For loading conditions applicable to seaplanes only the load factors and methods of computation approved by the Bureau of Aeronautics shall be used. This includes catapulting.

Accelerometer Tests

Tests in actual flight by means of accelerometers have been the basis for determining most of the load factors of the Engineering Division. Lieutenant Doolittle made a considerable number of tests and obtained observations on a Fokker PW-7 single-seater pursuit airplane in various maneuvers. Static tests of the airplane used showed that it could withstand nine times its weight in loading. The highest velocity attempted in dive was 162½ miles per hour. From a series of lower air speeds data were obtained from which a curve (Fig. 4) was plotted showing the variation in the increase of accelerations with the speed in pulling out of a dive. Considering the high speed in level flight in this particular case as 157 miles per hour, it was evident that the margin of safety for pursuit airplanes was not sufficient, and consequently the Engineering Division requires a factor of 12. The accelerations recorded in barrel rolls are also very instructive. The greatest loading obtained in this case was in starting the roll at 160 miles an hour and pulling back sharply on the stick with the resultant acceleration of 7.2 g, identical with the loading pulling out of a dive. Accelerometer readings in landing were taken on a JN-4H. The results showed a maximum loading of 2.7 for a smooth three-point landing and 5.2 for a tail-high landing. A material factor of 2 is used in comparing acceleration loads with the load factor.

Advances in Aerodynamics

The most noteworthy advances in aerodynamics center about the applications of theoretical hydrodynamics. Professor Witozinsky[2] has taken the classical hydrodynamical theory and introduced practical checks on the theory at various stages so as to make the theory correspond with known facts, step by step, such as relocating the boundaries and points of discontinuity and stagnation. Laboratory tests of pressure distribution in the Eiffel Laboratory have confirmed the theoretical values of Witozinsky as being unusually close to the experimental and within the allowable error in aerodynamics.

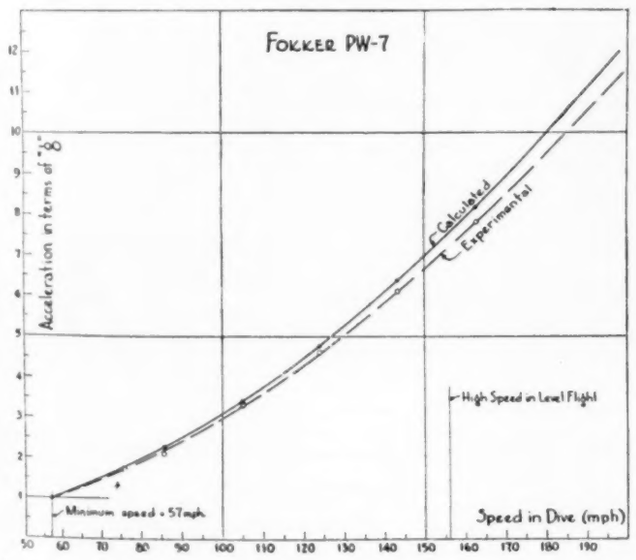
Fokker PW-7
Acceleration in terms of "g"
Calculated
Experimental
High Speed in Level Flight
Minimum speed - 57 mph
Speed in Dive (mph)
50 60 70 80 90 100 110 120 130 140 150 160 170 180 190

Fig. 4 Calculated and Observed Accelerations in Pulling Out of Dives

Prandtl's methods of calculating the drag and differentiating between profile and induced drag have influenced design so that the term "span loading" of an airfoil is spoken of rather than "aspect ratio." In the calculation of the drag of an airfoil for predicting airplane performance, the profile drag of the wings may be considered constant for all angles of attack in flight, and is calculated under the heading of parasite resistance. The following equation is used as the basis for calculation:

$$C_D = \frac{C_L^2 \times \text{Area}}{\pi \times (\text{Span})^2} + C'_D$$

In this equation the first term gives the induced drag and the second term the profile or friction drag. It is evident that the term for induced drag can be reduced to an expression involving aspect ratio, if desired. A convenient formula is—

$$\text{Induced Drag} = 125 \frac{(\text{Lift})^2}{(\text{Span})^2 \times (\text{Velocity})^2}$$

(Units: lb., ft., m.p.h.)

The tendency to reduce exposed structures coupled with the desire for a large span has led to the adoption of semi-thick and thick wings in the modern airplane. An airplane has been built, the XCO-5, (see Fig. 5) designed particularly for altitude performance. It has a semi-thick wing section with high lift characteristics and particularly good L/D at high angles of attack. It is possible that an airplane with this type of characteristics may lead to other developments.

Fig. 5 The New Altitude Airplane XCO-5

[This plane has the high-lift wing section (S. T. Ae. 27a). Note the side-type exhaust-driven supercharger. Duralumin sheet used on leading edge of wings in place of veneer. Pilot's cockpit weatherproofed and heated from engine.]

Stability

A study of longitudinal stability has been made at McCook Field by Mr. Dormoy. By a consideration of stick forces and pitching moments, and by making careful tests of a large number of different airplanes and studying the curves obtained therefrom, it has been made possible to predict, with sufficient accuracy, the longitudinal stability of an airplane being designed. The results are purely practical and serve the dual purpose of making possible the design of a good flying airplane and also correcting defects in existing airplanes due to poor judgment.

Materials—Metals vs. Wood

The metal airplane is continuing to gain in favor. Metal wings have not exhibited sufficient advantage over wood wings of the size which is common at the present time. There is also considerable opposition, although not yet put to practical test, to metal covering of wings. However, an experimental observation airplane made entirely of metal has just finished its static proof loading, and this airplane represents a compromise in that the lower surface of the wings is to be covered with fabric and the upper surface, including the leading and trailing edges, with corrugated aluminum. This is made necessary for maintenance and inspection purposes.

Fuselages

The steel-tube fuselage (Fig. 6) has become quite common, and is now being improved by substituting chrome-molybdenum steel, which allows a further saving in weight due to its higher strength and at the same time is readily welded with less detriment than other steel.

	Tensile strength, minimum, lb. per sq. in.	Yield point, minimum, lb. per sq. in.
Chrome-molybdenum steel tubing	95,000	60,000
Ordinary steel tubing of 1025 steel	55,000	36,000

[2] *Revue Générale de L'Aeronautique*, no. 4, 1924.

Some of the larger fuselages are now being built with an all-tubular framework without wires (Fig. 7). A typical example of improvement is the steel fuselage for the DH-4 which weighs 245 lb. including the covering, as against the old-style fuselage weighing 325 lb. Duralumin fuselages (Fig. 8) are made up of tubes riveted into fittings or by means of corrugated aluminum coverings and stamped bulkheads with structural bracings. It is difficult to say whether duralumin will gain favor in the immediate future over alloy-steel tubing or not.

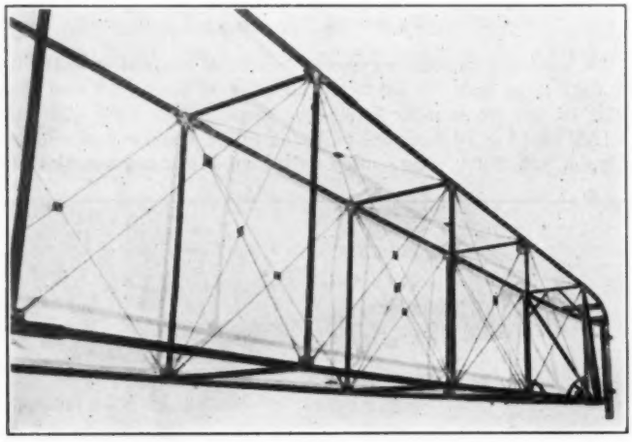

FIG. 6 A TYPICAL WELDED STEEL-TUBE FUSELAGE WITH CROSS-BRACE WIRES

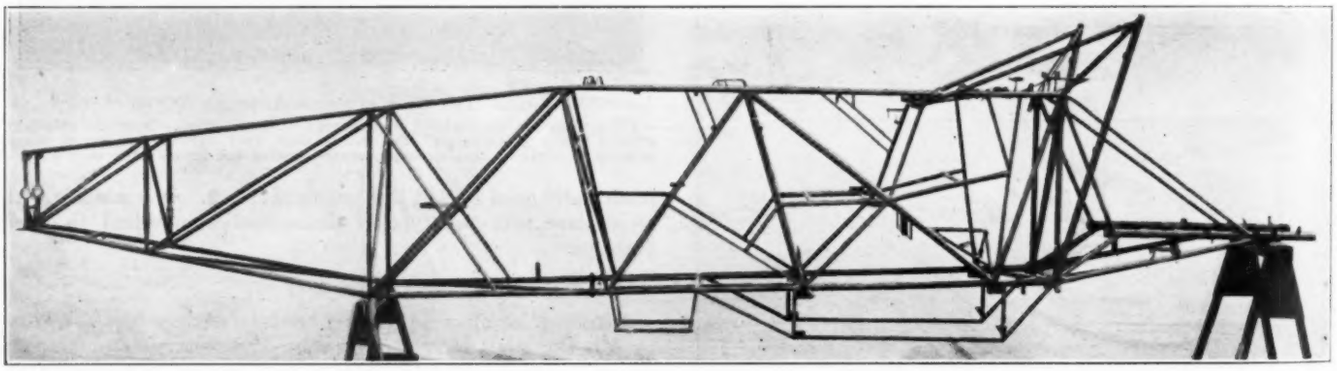

FIG. 7 A WELDED STEEL-TUBE FUSELAGE OF THE RIGID TYPE WITHOUT CROSS-BRACE WIRES

WINGS

The solid-wood I-beam for wing spars is being supplanted by the box spar, due in a measure to increase in span accompanied by a limitation to single-bay structures and also to thicker wing sections. The difficulty in developing a satisfactory metal spar lies in the fact that the metal used in these individual sections to carry the stresses is subject to local failures by buckling or crinkling. Since the Air Service is not ready to replace fabric wing covering by metal sheet due to maintenance complications, individual spars have been built and tested under standard loadings. As a result of a series of tests on spars 15 in. deep designed to carry loads in a heavy bombing plane, it has been found that the spar built of chrome-molybdenum steel tube and one having duralumin-tube flange members (Fig. 9) and a steel-tube web show up the best from the standpoint of weight of spar to load carrying. The welded chrome-molybdenum spar is slightly stiffer and it is not subject to as high secondary stresses as the combination type. In the same series of tests there was a duralumin spar and built up girder structure which showed up remarkably well. The Engineering Division has also tested an extruded I-section design for a lighter loading and found that it would work satisfactorily. Several types of extruded beams are being further tested to develop a type which will be satisfactory for observation airplanes. Duralumin box spars, open channel structures, and plate-girder spars are the best metal type, so far, for 6¼ in. depth. Extruded spars are good only in shallower types. The development of duralumin tubing and its subsequent use in airplane construction, the development of extruded shapes, I's, bulbs, angles, etc., for wing beams and struts represent progress in new materials for airplanes.

Metal ribs have been used satisfactorily, and we find them at present on the Loening Amphibian stamped out of sheet duralumin. Duralumin is also used for a veneer substitute on the leading and trailing edges of certain wings.

It has been stated that military airplanes could be of flimsy construction because they are not constantly in the air, and that therefore the commercial airplane should be heavier in order to be rugged and require less maintenance. It is believed that this particular point is a little misstated and should rather read that although military airplanes require higher load factors for the maneuvers to which they are subjected, yet in order to obtain high performance and efficiency it is necessary to build more efficient though less rugged structures even if the cost of fabrication and maintenance becomes slightly increased.

GASOLINE TANKS

The question of reducing weight has affected the choice of material in building gasoline tanks. The following comparative figures, as conservative values for average-shaped tanks of 90 gal. capacity, show striking improvement:

	Lb. per gal., approx.
Terne plate	1.00
Aluminum, welded	0.60
Duralumin, nickel plated, soldered, and riveted	0.35–0.40

A 60-lb. saving in weight can be shown in this phase alone.

MAGNESIUM ALLOYS

The development of a practical method of casting magnesium alloys has made possible their use for at least experimental purposes for supercharger casings, instrument and camera casings, and the like. Magnesium-base alloys usually weigh approximately 65 per cent of those of aluminum. They have a number of unusual characteristics which might be termed disadvantages in the light of present practice, but which are not difficult to overcome.

CORROSION PREVENTION

The use of metal structures at once brings up the problem of fatigue and of corrosion. The former is being given considerable study—no new conclusions are available at this time. Protective coatings based on work in corrosion prevention are recommended as follows:

Steel Tubing. Interior protected by filling with hot linseed oil after welding.

Steel, Aluminum, Duralumin. Two coats primer, iron oxide, or aluminized varnish. Basic pigments, as red lead, are not to be used on duralumin.

Aluminum and Aluminum Alloys. When exposed to an unusual service, viz.: in gasoline and cooling systems, and to salt water, Z-D process, consisting of baking in a water-glass solution. This is used for carburetor bowls.

Magnesium Alloys. Necessary to prepare the surface first by Parkerizing, forming a magnesium phosphate or dilute nitric acid; then apply enamel or duco.

Anodic Treatment for Aluminum and Duralumin. Consists of passing

an electric current through a solution of bichromate of potassium, using the metal as the anode. The current is passed at 35 volts rising to 60 volts in one hour. Anhydrous oxide is believed to result. This is now undergoing extensive salt-spray test.

Plating. Cadmium plating on various metals has proved as good with a 0.0003 in. thickness as zinc plating with 0.001 in. Consequently it is more convenient to use cadmium, especially in the case of close fits, without the necessity of undercutting to allow for the plate.

GASOLINE

Specifications for aviation gasoline now call for a maximum allowable critical solution temperature with aniline of 61.5 deg. cent.

Naphthene should be a maximum and paraffin a minimum for the best anti-knock quality in gasoline. This is tested by the relative lowness of the temperature of critical solubility of the gasoline in aniline.

Paraffin: Naphthene	Critical temperature	Source (typical)
50:40	40 deg. cent.	California
80:15	66 deg. cent.	Eastern

ENGINES

The most successful aircraft engines at the present time are really refinements of types available for some years past. Some of these improvements are greater compactness, resulting in lighter weight and greater rigidity; higher crankshaft speeds; improvements in valve-operating mechanisms, valve cooling, and valve materials; improvement in bearing design; and improvement in volumetric efficiency. The success of the inverted engine of the air-cooled V-type, of reduction gearing, and of the rotary inductor supercharger, has contributed the largest share to recent progress with engines.

TABLE 3 TYPICAL VALUES ON TYPICAL ENGINES

	Maximum service r.p.m.	Brake mean effective pressure, lb. per sq. in.
Liberty-12	1700	115–120
Aircooled Liberty	1800	125
Curtiss D-12	2000[1]	140
Curtiss V-1400	2100–2500	140 (estimated)
Packard V-1500	2100–2300	135
Packard V-2500	2000	135
Curtiss R 1454 (radial aircooled)	1800	135

[1] The D-12 has been run successfully at 2800 r.p.m.

Crankpin forces run about 1000 lb. per sq. in. of projected area with a rubbing speed about 35 ft. per sec., giving a value of pv = 35,000. The Liberty-12 uses about 25,000, whereas the high-speed D-12 has experimentally run up to 50,000.

Bronze-backed bearings are being supplanted by steel-backed ones for greater rigidity of support. For rigidity also outside diameters of crankshafts have been increased.

The type M air-cooled cylinder developed by the Engineering Division has many typical features. The valves, which are both of glass-hard steel, operate in glass-hard tungsten-steel guide bushings. The exhaust valves are internally cooled by a mixture of sodium and potassium nitrates contained in the hollow stem. The enclosed force-feed lubrication, constant-clearance valve gear is a very important adjunct. The pistons for aircraft engines are coming out with shorter skirts so as to be in style. The mean effective pressure for the single cylinder at 1800 r.p.m. runs between 145 to 155 lb. per sq. in. The success which has attended the work of the air-cooled Liberty-12 with its efficient cooling system eliminating cooling trouble in the rear row of cylinders, has justified the design of a 24-cylinder X type air-cooled engine of 4520 cu. in. displacement, which is now in the process of construction (see Figs. 10–12). In addition to having cylinders similar to the type M cylinders, it will have a crankshaft of large diameter using roller bearings for the main bearings and plain ones on the rods. It will be equipped with centrifugal supercharger and reduction gear. It is estimated that it will weigh 2 lb. per hp., including the accessories and supports.

GEARING

The aircraft industry has taken advantage of the improvements in the gear-cutting industry so that highly reliable reduction gears have been obtained weighing somewhat less than 0.2 lb. per hp. Although gearing was employed during the war in Europe, it has been only recently that it could be adopted without considerable increase in the weight of the power plant. Typical reduction gears show tooth speeds in the vicinity of 3500 ft. per min. accompanied by tangential loads of 2000 lb. per in. of face width. The combination of hardness, strength, and accuracy has only recently permitted operation under these severe conditions. Shock-absorbing couplings have been found necessary to protect the gears from the effects of violent engine-torque variations. At the present time spur gears which show a 20-deg. pressure angle are being employed.

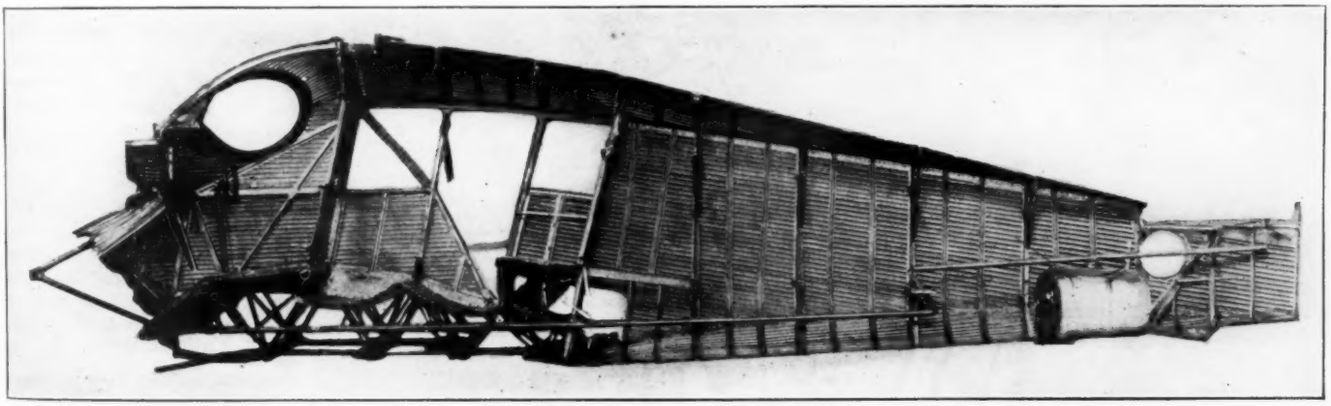

FIG. 8 CROSS-SECTION OF A JL-6 FUSELAGE SHOWING A TYPE OF BUILT-UP BULKHEADS WITH CORRUGATED DURALUMIN SHELL

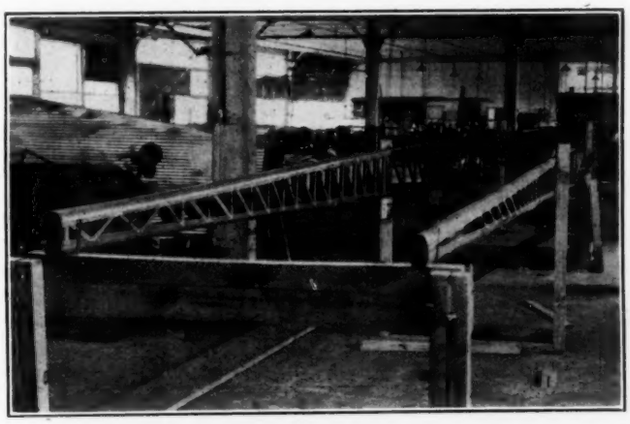

FIG. 9 A BUILT-UP RIVETED DURALUMIN WING SPAR

RADIATORS

Radiators slung under the engine at an inclination to the vertical have been developed and tested so that now these tunnel types are considered as having practically no more resistance than wing radiators.

SPECIAL ENGINES

Progress on engines will not be completely reported without mentioning the advancement in producing the 500-hp. Packard

No. 1 A (1500 cu. in.), weight 710 lb.; and the 800-hp. No. 1 A (2500 cu. in.), weight 1135 lb.; and the Curtiss 500-hp. No. V 1400, weight 660 lb. Experimental engines of the above types are being used on various projects, the V-1400 having been flown in the Pulitzer and Schneider Cup Races, and the Packard engine in the PN-9 planes. These engines are being further tested with and without gears. The Almen barrel engine has completed certain tests, but is not yet advanced beyond the experimental stage; similarly the cam engine which substitutes a cam mechanism in place of connecting-rod devices, making for simplicity. The Curtiss air-cooled radial R 1454, delivering over 400 hp., has finished 20 hours with minor failure in master connecting-rod assembly.

PROPELLERS

With the increase in engine speeds must go increase in propeller speeds unless gearing is resorted to. This has been met very effectively by the use of drop-forged aluminum-alloy propellers which make possible the use of very thin sections. Wind-tunnel tests show that there is no comparison in efficiency between the thin and thick sections, and with tip speeds between 700 and 800 miles per hour the metal propeller has actually displaced the wooden one, giving from 5 to 10 miles per hour increase in airplane speed.

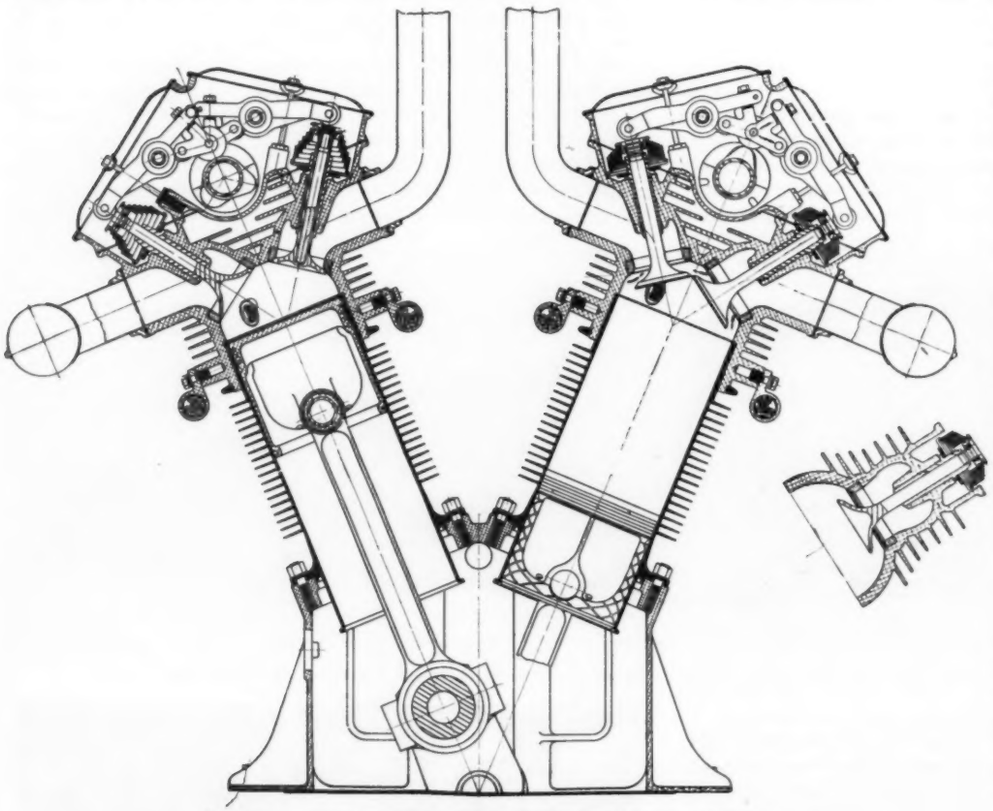

FIG. 10 CROSS-SECTION OF THE AIR-COOLED LIBERTY-12 ENGINE

(The totally enclosed valve-operating mechanism and the salt-cooled exhaust valve are shown. Note the steel sleeve and lower cylinder, and cast-aluminum head. Intake is from the outside of the V, and exhaust through the inside of the V, or opposite to standard water-cooled-engine practice.)

These propellers may be made up with split hubs and with separate blades. From the service viewpoint it is highly desirable for the propeller to have blades which can be separately removed, in consideration of transportation, repair, and interchangeability for different types of airplanes, etc. With various adapters the same propeller blades can be used for various types of engines and airplanes within certain limits, and the angles of pitch settings adjusted at the hub accordingly. This development has instigated another development in the case of larger and medium-speed engines by the experimental use of magnesium with a saving in weight of approximately one-third. In the case of very large-diameter and slow-turning propellers, especially for airships, built-up propellers have been made up to 25 ft. in diameter with balsa-wood core covered with strips of veneer.

It is now possible to make an efficient light weight, three-bladed propeller which is useful for pusher installations, and which may find its place as a compromise between the two- and four-bladed propellers.

Standard wooden propellers which were formerly covered by aluminum leaf applied by hand to protect the wood against moisture changes, are now being finished with a varnish containing aluminum powder and giving practically the same results with less cost and effort.

AIRCRAFT EQUIPMENT—MANIFOLDS

A large number of crash tests have been made by the Engineering Division by running worn-out airplanes at high speed against a thick concrete wall. A very thorough study of this has been undertaken, using the slow-motion movie camera for observing each test (see Fig. 13). The DH-4B airplane has been the most common offender in catching fire after wrecks, and so the results of that type alone are given. Out of nine DH-4B's with various types of exhaust manifolds, there resulted five fires. Four of the nine were equipped with standard stacks as used in the service today, and three of the four took fire. To show that the fires were due to the hot exhaust manifolds, eleven were crashed with no manifolds, with no fires resulting. It being necessary to have some sort of manifold air-cooled exhaust stacks were designed and fitted as shown in Fig. 14. Ten planes so equipped were crashed and no fires resulted. It is believed, therefore, that it will be highly desirable in case of commercial aircraft to have air-cooled exhaust manifolds, not only for the fire-hazard elimination but for reducing the noise from the exhaust of the engines.

PHOTOGRAPHY

Photographs have been successfully taken from the air at night by means of setting off a 35-lb. flashlight charge towed behind an airplane flying at from 2000 to 3000 ft. altitude. These photographs show the ground in a very clear manner and will undoubtedly change the practice somewhat of moving troops under cover of darkness, since the cover has been removed.

By means of a new process it is now possible to take a photograph in the air, develop and print it, and deliver it by dropping it from the air within ten minutes after exposure. The photograph can be used as a negative also if desired.

A preliminary test has been run showing unusual promise in haze penetration in aerial photography with the new kryptocyanine film which is sharply sensitive in the infra-red only.

The four-lens mapping camera has been put on a status of production. The advantage of the four-lens camera is obvious.

INSTRUMENTS

Instruments for aerial navigation in any kind of weather are being developed, and considerable progress is being made. Long navigation flights have been undertaken with instruments now available, sometimes as much as four hours at a time being out of sight of land, and yet finished not appreciably far from the calculated course. For long flights accurate meteorological information is very necessary, especially as regards winds at altitudes.

The induction compass has successfully demonstrated its value since it allows an accuracy within $1\frac{1}{2}$ deg., whereas the accuracy of the ordinary magnetic needle compass cannot be closer than

5 deg. The induction compass employs the principle of a rotating coil which seeks to maintain a definite position with respect to the earth's magnetic field. This instrument has now been placed on a production status.

An automatic recording compass and log has been experimented upon and has successfully recorded the air course traveled by an airplane.

The most difficult problem which is as yet not completely solved, but upon which progress is being made, is in the case of an altimeter which will indicate actual distances above the ground. Preliminary tests have shown it entirely practicable to measure the distance above the ground as a variable function of capacity in one of two radio circuits in an airplane. It is expected that results from a practical installation can be announced shortly.

A new altimeter standard replacing the isothermal standard has

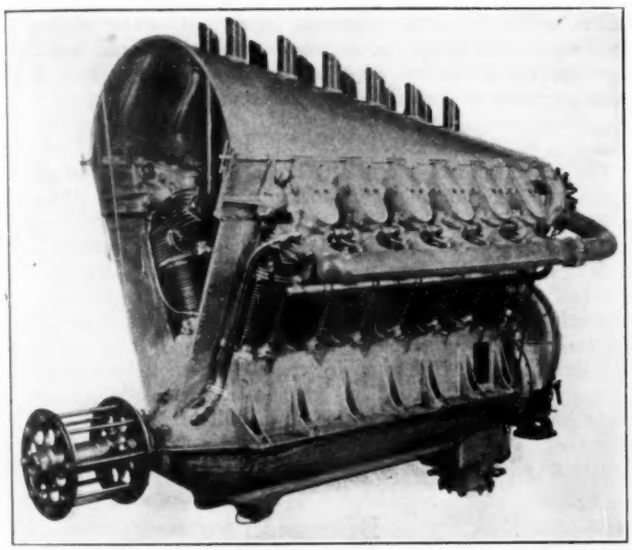

Fig. 11 The Air-Cooled Liberty-Engine with the Wind Scoop
(Note the single carburetor and centrifugal distributor at the rear.)

Fig. 12 The Air-Cooled Liberty Engine Installed Inverted in an Observation Airplane (XCO6-C)
(This makes possible a high center of thrust and better vision forward.)

been adopted. An altimeter has been developed giving correction for ground temperature.

A new, very sensitive rate-of-climb meter has been developed.

An experimental optical drift sight, recently tested, mounted on the instrument board should be of advantage in navigation, not to mention its particular benefit in mosaic photography, bombing, and observation work.

Higher air speeds, revolutions per minute, and altitudes have necessitated the redesign of existing instruments so as to give sufficient range of scale for increased performances. In this connection might be mentioned the fact that the service-airplane instrument board is being simplified by arranging the scales in a vertical and compact set.

Under the caption of aids to navigation should be mentioned the proposed test this winter at Croydon of landing in a fog. The airplane will locate the airdrome by radio; pick the right line of approach from a leader cable; and a line of neon lights along the leader cable on the ground will show when to flatten out in gliding down by indications from the cable. Of course, stability at a low landing speed is a very necessary quality for the airplane.

Radio Beacon

The radio directing beacon located near Dayton has successfully guided airplanes and held them to within ten miles either side

Fig. 13 One of the Numerous Crash Tests Run at Dayton in the Interest of Elimination of Fire Hazard in Wrecks
(Note the aluminum air-cooled exhaust stacks which have been developed through these tests, and with which no fires have resulted.)

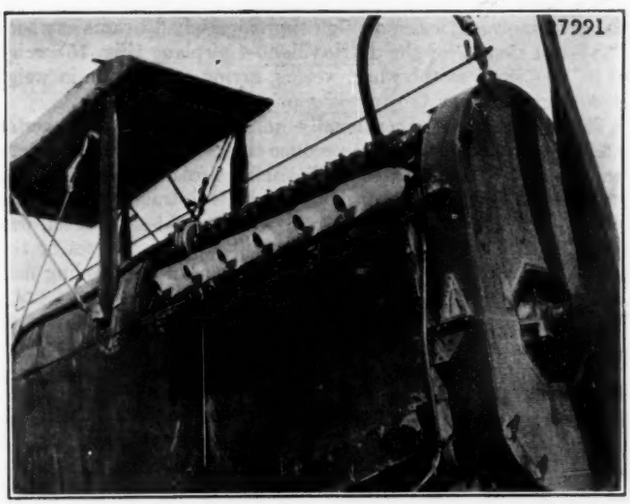

Fig. 14 A Close-Up of the Air-Cooled Aluminum Exhaust Stacks Installed on a Liberty-Engined de Havilland Plane

of the direct course, and has been heard 200 miles away and followed very successfully. The beacon periodically emits signals of two separate letters 90 deg. apart, with the course in question bisecting for this angle. The Air Mail Service has been furnished complete data on this and plans to try it out for its purpose.

A mechanism has been arranged and tested which will automatically indicate by a series of lights on the instrument board whether the pilot is on his course or not.

Electrical Equipment

With the advent of starters, night-flying equipment, and other electrical appliances, it has been necessary to consolidate electrical units, so that with the present installations that are coming out it will be very helpful even to active pilots to learn considerable about electricity.

Beacons for night flying have been improved by the introduction of a lamp-changing mechanism which automatically replaces a burned-out lamp by a new incandescent lamp, making a signal which indicates this change.

Various types of starters have been evolved to eliminate the old-fashioned method of cranking the engine by means of the propeller. There is the electric starter such as is used on automobiles. There is also the hand crank which attaches to the rear end of the engine and projects from the side of the fuselage, so geared as to reduce the effort to a minimum and yet turn the engine over sufficiently to start it. There is also a portable electric-motor starter which may be inserted in place of the hand crank. Still another type is the inertia starter. This functions by the energy stored up in a flywheel of minimum weight rotating at some 25,000 r.p.m. so as to furnish sufficient torque by its inertia to start the engine.

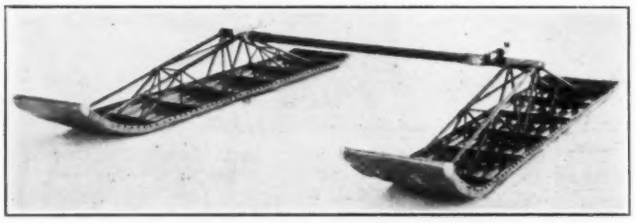

Fig. 15 A Typical Set of Metal Skis Which Compare Favorably in Weight with Wheels

There is still another, an electrical-mechanical combination, which substitutes a small electric motor in place of the hand crank for bringing the flywheel up to speed. Just which type will survive will depend upon further developments, with reduction of weight being given considerable importance.

Skis—Wheels and Tires—Brakes

Skis have been built which allow the very efficient use of airplanes on snow and ice, and weigh approximately the same as wheels. The latest design for the de Havilland-4 airplane (Fig. 15) weighs 39 lb., the same as the wheel weighs, giving a reduction in weight of 30 per cent over the previous one.

The Air Service is continually aiming to standardize certain interchangeable parts so as to reduce the cost of manufacture and maintenance. This is particularly true of airplane wheels and tires. Standardization is being concentrated on the straight bead replacing the old clincher type. The 28 × 4 straight-side wheel, drop center, is being standardized for pursuit work; two sizes of tires can be placed on this rim according to the kind of landing fields to be used. A 36 × 6 tire can be used as well as the 28 × 4. Disk wheels are being experimented upon largely because of the question of brakes for airplanes.

The advantage of being able to land an airplane and safely shorten its roll from 980 to 340 ft. is evident at the outset. This has been done with the DT-2 airplane. The brakes for each wheel are independently connected to the cockpit and will also assist in taxiing. It has been found that it is necessary to set forward the landing gear on some airplanes and also strengthen the tail skid on quite a few service ships. The use of brakes will show the greatest advantage in the case of high-speed aircraft, and may also allow designers to adopt in special cases a higher landing speed. No sooner does a scheme or device prove itself and make for an increase in the safety of aviation, than there springs up a tendency to use the improvement to effect an increase in performance. Consequently we may expect higher landing speeds. There is nothing new, of course, in brakes, but, just as with other things that have been rejected in the past, new circumstances make them feasible. This is intelligent progress.

Lighter-than-Air Craft

Duralumin for the first time has been used by the Army Air Service in the construction of an airship car; in this case for a one-man training airship, the TE-1, giving an estimated saving of 30 per cent in weight. A blower has been developed delivering 10,000 cu. ft. of air per min. at 1 in. of water, being twice the delivery capacity at two-thirds the weight of the lightest previous airship blower developed.

A grab winch mounted on a very maneuverable tractor has been developed to reduce the number of personnel in the ground handling of lighter-than-air craft.

The RS-1 airship, semi-rigid, 750,000 cu. ft. capacity, is now being "hangar tested" at Scott Field. Many new engineering problems had to be met in this construction. Tests with water models had been made and many engineering data obtained, and now these data are being checked against the full-scale ship. One of the main purposes of this airship is for carrying airplanes.

Conclusions

The general progress from a technical viewpoint may be considered as further refinement on work of previous years. More and more specialized engineering work is being required to carry on this advance, which, actually measured in performance and efficiency, has equaled any previous periods which might be considered. A particularly important advance was made in the second successful Army and Navy conference with manufacturers in Dayton in July for standardization purposes. Army and Navy standards are being adopted by engineering societies as standard aeronautical practice. These specifications include numberless parts such as nuts, bolts, cotter keys, pulleys, washers, shackles, hose liners, turnbuckles, hose clamps, steel wire and cable, tubing, aluminum alloys in sheets, rods, bars, tubes, and so on indefinitely.

Discussion

FOLLOWING the presentation of the paper, the author dealt with a number of questions asked by his auditors. Replying to John A. Stevens,[3] he said the Oleo-pneumatic gear shown in Fig. 3 was one method of dealing with shock absorption on landing gears. However, on the airplane shown in Fig. 12 no shock-absorbers had been used aside from ordinary balloon tires, and no visible defects were found after a number of hard landings. In regard to the type of joint used in the steel fuselages illustrated, about which Archibald Black[4] inquired, the author said that they were plain welded jobs with no reinforcement. The interiors of the tubes were protected against corrosion by forcing oil into them.

The author agreed with a statement made by Sanford A. Moss[5] to the effect that the poor maneuverability of airplanes at high altitudes was due to their not being provided with superchargers, and said that the matter of equipping all the purely military planes with them was under consideration. As to whether duralumin was as good as mild steel as regarded fatigue and durability, concerning which Grover Loening,[6] the presiding officer, asked, he stated that the information at present available went to show that it was inferior to steel in the matter of fatigue.

Replying to G. Titterton,[7] the author said that the triangular-shaped fuselage had not been considered during the last year or so at McCook Field. For airplanes that had to be maneuverable and in addition able to withstand shocks due to being catapulted, as they were on Navy carriers, he believed the rectangular fuselage was best. Chairman Loening demurred to this, stating that the triangular construction had great possibilities, particularly as the maximum loads on an airplane were likely to occur in such a way that it could be shown to be more economical.

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[3] Consulting Engineer, Lowell, Mass. Mem. A.S.M.E.

[4] Consulting Air Transport Engineer, Garden City, L. I., N. Y. Mem. A.S.M.E.

[5] Engineer, Mechanical Research Department, General Electric Co., Lynn, Mass. Mem. A.S.M.E.

[6] Loening Aeronautical Engineering Co., New York, N. Y.

[7] New York University, New York, N. Y.

Boiler-Water Conditioning with Special Reference to High Operating Pressure and Corrosion[1]

Prevention of Scale Formation on Evaporating Surfaces—Relation Between Chemical Used and Operating Pressure—Prevention of Corrosion of Surface in Contact with Boiler Water—Control of Non-Condensable Gases in Steam by Boiler-Water Conditioning

By R. E. HALL,[2] PITTSBURGH, PA.

IN JANUARY, 1922, an agreement was made between the U. S. Bureau of Mines and the Hagan Corporation of Pittsburgh, Pa., to conduct a coöperative investigation on the mechanism of scale formation in boilers, and related factors. The interest of the first party lay in the conservation of fuel which might be effected by a fundamental conception of the causes underlying boiler-scale formation; the interest of the second party was in adapting such conceptions to operating practice and in developing equipment therefor. The results of this investigation, especially their application to high operating pressures, are presented in this paper.

THE SCOPE OF BOILER-WATER CONDITIONING

It is not often that the chemist is able to shift responsibility to the engineer and find the latter passive in his attitude, but in the instance of preparing water for boiler use he has done so. The chemist for years has specified for this use water softened to a certified degree of hardness, and the engineer has concurred in this specification. What the latter really wants, however, is clean evaporating surfaces; and when he will make this the criterion for the chemist, specifications of water of varying degree of hardness must be displaced by others based on conditions in the concentrated boiler water itself. With the latter criterion, control of scale prevention becomes an exact operation amenable to an accuracy commensurate with all other operations in the boiler room.

The responsibility in boiler-water conditioning, however, includes more than clean surfaces. Corrosion in feed lines, economizers, and the boiler is a function of the condition of the water in contact, and must be controlled. Steam-line and turbine-blading deposits—the result of wet steam—must be obviated by the system of conditioning. By the chemical treatment employed, the amount and character of non-condensable gases in the steam must be controlled in accordance with the intended use of the steam. The responsibility in boiler-water conditioning does not end with the entrance of the water into the boiler, but with the passage from the boiler nozzle of steam, whose dryness and purity are defined by the uses to be made thereof.

Fig. 1, a diagram[3] of the surfaces at which it functions, gives a clearer conception of the scope of boiler-water conditioning. First, there are those surfaces in contact with water below steam temperature—that is, those at which no evaporation is occurring—at which corrosion may present the greatest problem, although scale deposition may also occur.

Second, there are those surfaces in contact with steam and water. These may be subdivided into (*a*) those in direct contact with the boiler water—that is, the evaporating surfaces—and (*b*) those which are in contact with boiler water because of entrained moisture in the steam. It should be noted that with (*a*) comes the end of the possibility of treating the water. Whatever is required for the protection and economic operation of the entire system must be done prior to this point.

Third, there are those surfaces in contact with condensing steam and water. For the purposes of power production and steam heating, greatest interest centers in the types of solid deposits which may be caused by the steam and the corrosive action of any non-condensable gases therein. In process work, however, the chemical effects of entrained solids and of non-condensable gases are of moment. The control of the character of the steam lies in the conditioning of the boiler water.

One other point in this diagram stands out prominently: Whereas the raw water used for make-up may be treated by an outside system or by an evaporator, the condenser leakage has a clear path

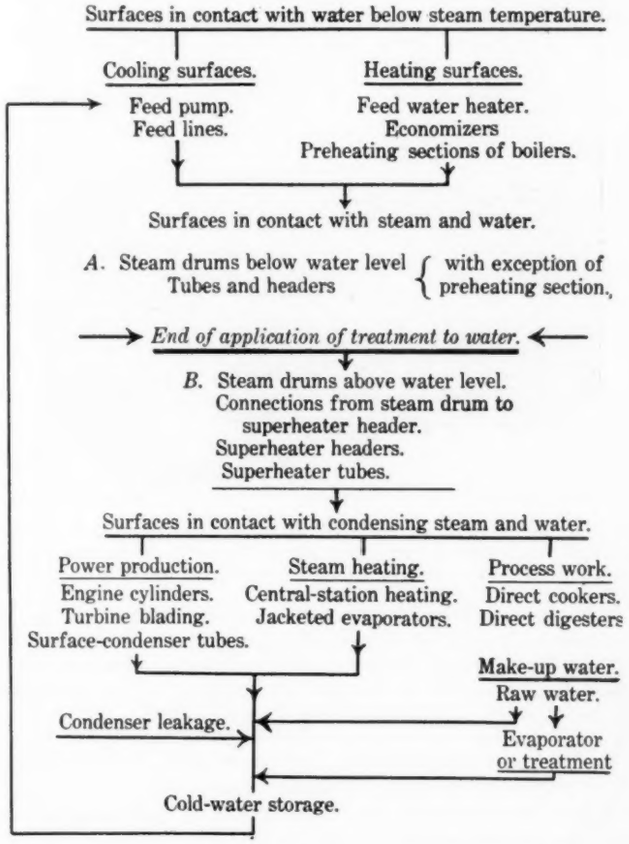

FIG. 1 SURFACES OF STEAM-GENERATING AND -CONSUMING SYSTEM

to the boiler, and only in a control held on the boiler water itself can its effects be obviated.

The problems of boiler-water conditioning may therefore be outlined as follows:

1 Prevention of scale formation on surfaces
   (*a*) In contact with water but at which no evaporation occurs, and
   (*b*) At which evaporation is occurring
2 Prevention of corrosion on surfaces (*a*) and (*b*) of 1
3 Selection of chemical treatment on the basis of non-condensable gases that are permissible in the steam
4 The control of sludges and soluble salts in the boiler water. Even when the entire make-up is composed of evaporated water and condensate, such control becomes necessary because of an irreducible minimum of condenser leakage
5 The removal of entrained moisture from the steam.

[1] Published with approval of the Director, U. S. Bureau of Mines.

[2] Physical Chemist, Pittsburgh Experiment Station, U. S. Bureau of Mines.

[3] The author wishes to acknowledge the assistance of T. A. Peebles, of the Hagan Corporation, in the preparation of this diagram.

Presented at the Midwest Power Conference, Chicago, Ill., January 26 to 29, 1926.

We shall now proceed to examine these phases of boiler-water conditioning, placing the major emphasis upon 1, 2, and 3 because they represent more particularly work done at the Bureau of Mines.

PREVENTION OF SCALE FORMATION ON EVAPORATING SURFACES

Emphasis has been placed upon the exactness with which any formation of scale can be controlled. In conjunction with the condition in the boiler water advisable for the inhibition of corrosion, the following expression serves as a general criterion for evaporating surfaces:

(A) Concentration in the boiler water of chemical used in treatment } = { Function of (*a*) the operating pressure, and (*b*) concentration of sulphate (SO_4) in the boiler water.

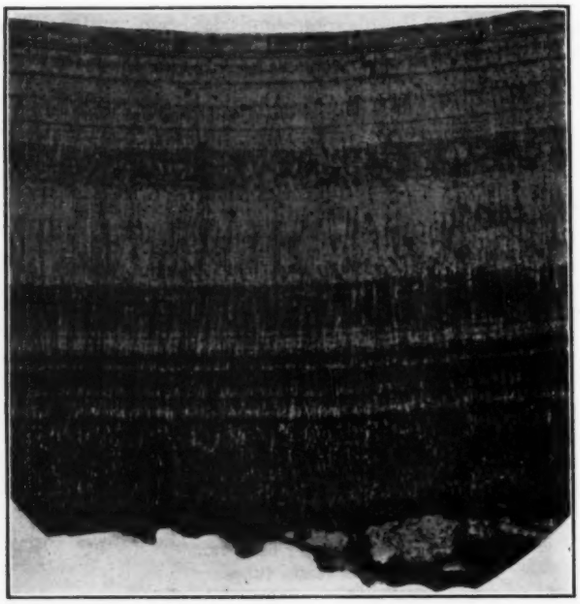

FIG. 2 THIN SECTION OF CALCIUM SULPHATE SCALE, SHOWING BANDED STRUCTURE AND GROWTH OF LONG, NEEDLE-LIKE CRYSTALS NORMAL TO THE BANDS. MAGNIFICATION, × 30

This expression makes no limitations regarding the type of feedwater to be used, or as to whether the water be conditioned by the use of evaporators, by pretreatment systems as lime and soda ash or the base-exchange processes, or by direct introduction into the boiler water of the chemical used in treatment. Neither does it specify whether the sludges produced shall be removed by filtration of the feedwater, by filtration of boiler water, or by blowdown. It is a generalized statement of the fact that the two major factors to be considered in prevention of scale formation on the evaporating surfaces are operating pressure and the sulphate concentration in the boiler water.

In order to define the term "chemical used in treatment," it is necessary to understand two principles governing adherent-scale formation on the evaporating surfaces. Evidence in proof of their validity has been presented elsewhere,[4] and they need only be stated briefly in this discussion as follows:

1 *Mode of Formation of Scale.* The adherent scales that grow in thickness are formed by deposition from the boiler water directly on the surfaces where found when the boiler is opened. This may be called deposition *in situ*, because the crystals responsible for the growth of the scale have never been present as individual particles free to follow the flow of the boiler water and be deposited in haphazard fashion on the surfaces. In a calcium sulphate scale, for instance, the axes of the crystals are normal to the evaporating surfaces, and growth along any individual crystal axis has proceeded for weeks or months. Fig. 2 is a thin section[5] of this type of scale photographed at low magnification by transmitted light.

There are three substances that deposit from the boiler water in this manner, namely, calcium sulphate, and calcium and magnesium silicates. The presence of calcium carbonate in adherent scales is due to the detention of loose crystals thereof in a matrix of one or more of the three substances mentioned. Thus in Fig. 3 the framework of the scale is evidently the large interlocking crystals of calcium sulphate, while in the interstices are found magnesium silicate and calcium carbonate.

2 *Temperature-Solubility Relations of Scale-Forming Materials.* The solubility of substances that form adherent scales decreases with temperature increase; conversely, those substances which separate from the boiler water as sludge increase in solubility with temperature increase. Therefore the chemical used in the final conditioning of the boiler water must be one that, if maintained at the concentration designated by the operating pressure and the amount of sulphate present in the boiler water, prevents the formation of any calcium sulphate or calcium and magnesium silicate at the evaporating surfaces and insures the separation of sludge-forming substances only.

In this discussion consideration will be given to two substances which meet these requirements, namely, sodium carbonate (Na_2CO_3, soda ash) and sodium phosphate (Na_3PO_4). The use of sodium silicate is excluded because calcium and magnesium silicate are

FIG. 3 THIN SECTION OF SCALE WITH FRAMEWORK OF CALCIUM SULPHATE AND WITH SUSPENDED MATERIAL ENTRAPPED IN THE INTERSTICES. MAGNIFICATION, × 30

responsible for adherent-scale formation. Any type of colloidal treatment is evidently out of question in view of the deposition of adherent scale *in situ*. *Sodium* carbonate and phosphate have been specified because they can be purchased more cheaply than other carbonates or phosphates. It must be recognized, however, that they are used because of their available carbonate (CO_3) or phosphate (PO_4) content, and that other carbonates or phosphates, as, for example, the potassium compounds, might be used if they were cheaper or if a special reason existed for their use. Thus barium carbonate ($BaCO_3$) may be used in preference to sodium

[4] Hall, R. E., A System of Boiler-Water Treatment Based on Chemical Equilibrium. *Jour. Ind. & Eng. Chem.*, vol. 17 (1925), pp. 283–90. Ibid. Fundamentals in the Conditioning of Boiler Waters, Proc. Eng. Soc. of W. Pa., December, 1925.

[5] The author is indebted to A. H. Emery, assistant geologist and petrographer, and G. H. Henneman, photographer, of the Bureau of Mines, for assistance in preparing these thin sections and photomicrographs. A paper regarding them will be published in the near future.

carbonate even though the cost is greater, in case it is necessary to decrease the concentration of soluble solids in the boiler water other than by blowdown. Henceforward, therefore, only the CO_3 and PO_4 concentrations will be considered, as it is they which are effective in maintaining satisfactory conditions in the boiler water.

The general expression (A) may now be written in more specific form. Regardless of any pretreatment which may have been given to the feedwater, the essential relation to maintain in the boiler water is expressed thus when soda ash is used for the purpose:

$$(B) \quad CO_3 > K_{1\ (\text{at operating pressure } p)} \times SO_4.$$

If sodium phosphate is used then the expression becomes—

$$(C) \quad PO_4 > K_{2\ (\text{at operating pressure } p)} \times SO_4^{3/2} \times D^{1/2}{}_{(SO_4)}$$

In these expressions CO_3, PO_4, and SO_4 are preferably measured in parts per million, although grains per gallon may be used as well. K_1 and K_2 are specific for CO_3 and PO_4, respectively, and are constants for a definite operating pressure p, but vary with variation of the operating pressure. D refers to the relation of ionic to total SO_4 in the boiler water, and is a function of the operating pressure and of the total ionic concentration of the boiler water. The presence of the hydroxide essential for inhibition of corrosion is assumed (100–200 p.p.m.).

The derivation of these expressions is based on the laws of physical chemistry,[6] and is not germane to the purpose of this paper. We shall proceed directly, therefore, to illustrate their practical application, and shall choose the common operating pressure of 150 lb. gage for this purpose.

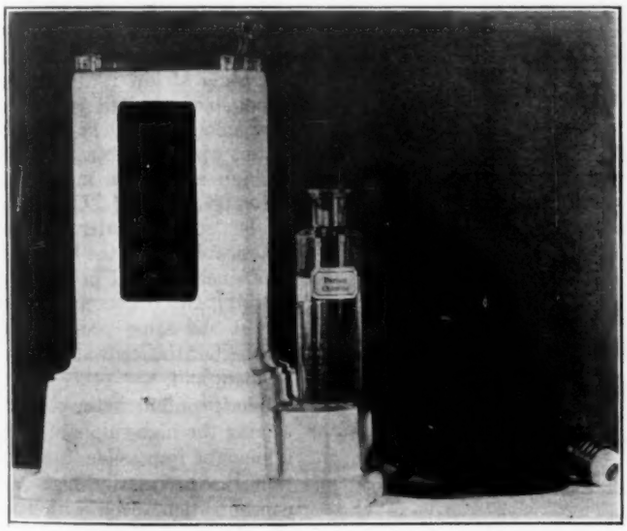

FIG. 4 FRONT VIEW OF SULPHATE CONCENTRATION GAGE

EXAMPLE OF CONDITIONING WITH CO_3

At this pressure for conditioning with soda ash,

$$K_1 = 8.83 \times 10^{-2}$$

if concentrations are expressed as parts per million. Thus, if the sulphate concentration in the boiler water is 1000 p.p.m., the concentration of CO_3 therein must be slightly more than 88 p.p.m. (90 to 120 would be satisfactory) to insure absence of adherent-scale growth. If the sulphate is but 500 p.p.m., then the maintenance of a CO_3 concentration of 50 to 75 p.p.m. in the boiler water is sufficient. As a rule it is best to determine in each plant what sulphate concentration corresponds to economical blowdown practice. Thereafter, the maintenance of this sulphate concentration serves to control blowdown and defines a constant concentration of CO_3 which must be present in the boiler water.

The simplicity of this control is evidenced by the apparatus necessary[7] in the boiler room for determining the SO_4 and CO_3 concentrations. Figs. 4 and 5 show the apparatus used for determination of the SO_4 concentration. Into the glass jar is introduced a sample of filtered boiler water (10 to 100 cc. according to the amount of SO_4 therein), and 10 cc. of acidified barium chloride solution is added, whereupon a finely divided white precipitate is formed. Sulphate-free water is next added until a brightly illuminated slit at the rear of the specimen jar becomes distinctly outlined to the eye. The visibility of the slit represents a definite dilution of the contents of the jar, and the quantity of SO_4 in the boiler water is read directly in parts per million from the scale etched on the jar.

Fig. 6 shows the apparatus for determining CO_3. A 100-cc.

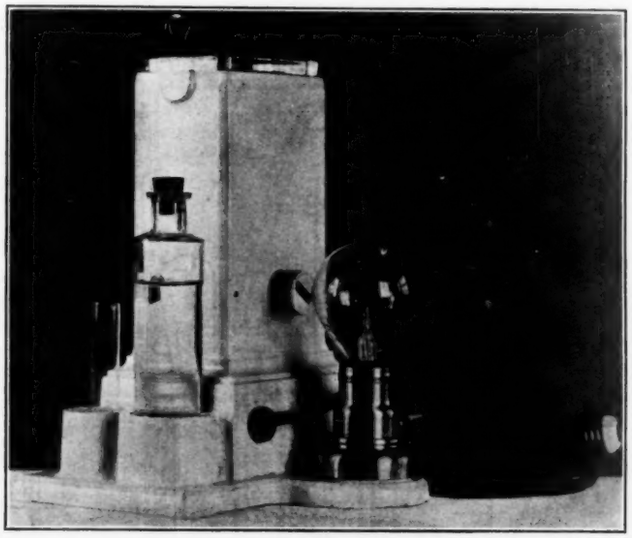

FIG. 5 REAR VIEW OF SULPHATE CONCENTRATION GAGE

sample of boiler water filtered in a and automatically measured in b, with a few drops of phenolphthalein indicator added, is treated with acid from the large barrel of the burette until the red color of the indicator disappears. The addition of a few drops of bromophenol blue indicator now colors the sample blue. Acid is added from the small barrel of the burette until the blue changes to green. The number of cubic centimeters of acid drawn from the small barrel multiplied by a factor (by 20 in case $N/30$ acid was used) gives directly the CO_3 concentration of the boiler water in parts per million.

The satisfactory feature in this control lies not only in its simplicity; as the determinations are made on the concentrated boiler water, the allowable limit of error in the determination is much greater than for titrations on the dilute feedwater, and any errors made are readily remedied.

EFFECT OF SODA ASH IN THE BOILER

When soda ash is used as conditioning chemical at the operating pressure under consideration the evaporating surfaces usually become covered with a thin, porous film consisting largely of calcium carbonate, unless unnecessarily high blowdown is resorted to. It is characteristic of this film that it does not increase in thickness unless the concentration of CO_3 in the boiler water is deficient. It is probable that this film, because of its ready permeability by water, is very slightly detrimental to the transfer of heat to the boiler water, and it may offer some protection against corrosion, though the author considers this doubtful.

EXAMPLE OF CONDITIONING WITH PO_4

However, if one desires to be free from the calcium-carbonate film, the conditioning of the boiler water may be accomplished by means of PO_4. The character of the sludge produced is quite different, and the film on the evaporating surfaces is not in evidence. The cost in this case is about fourfold that when soda ash is used.

For the operating pressure of 150 lb. gage, and the use of PO_4 in conditioning the boiler water,

$$K_2 = 1.64 \times 10^{-4}$$

[6] A derivation will be found in reference 4.

[7] Hall, R. E., Otto, H. A., and Jackson, H. A., Apparatus for Control of Boiler Water Treatment Based on Chemical Equilibrium. *Jour. Ind. & Eng. Chem.*, vol. 17 (1925), pp. 409–410.

when concentrations are expressed as parts per million. In the expression giving the relation of PO_4 to the SO_4 concentration of the boiler water, however, is found the term D relative to the ratio of ionic to total SO_4 in the water. This ratio changes with change in concentration of the SO_4; at the operating pressure under discussion for 1000 p.p.m. of SO_4, $D = 0.65$; for 2000 p.p.m. of SO_4, $D = 0.59$. Substituting these values in expression (C), it is found that for a concentration of 1000 p.p.m. of SO_4 in the boiler water, the essential concentration of PO_4 necessary to prevent adherent-scale formation is slightly more than 4 p.p.m., and for 2000 p.p.m. of SO_4 slightly more than 11 p.p.m. It will be satisfactory, therefore, under the conditions stipulated, to maintain a phosphate concentration of from 15 to 25 p.p.m. in the boiler water.

The apparatus for determining the SO_4 concentration has been described. That for determining PO_4 may be an adaptation of the

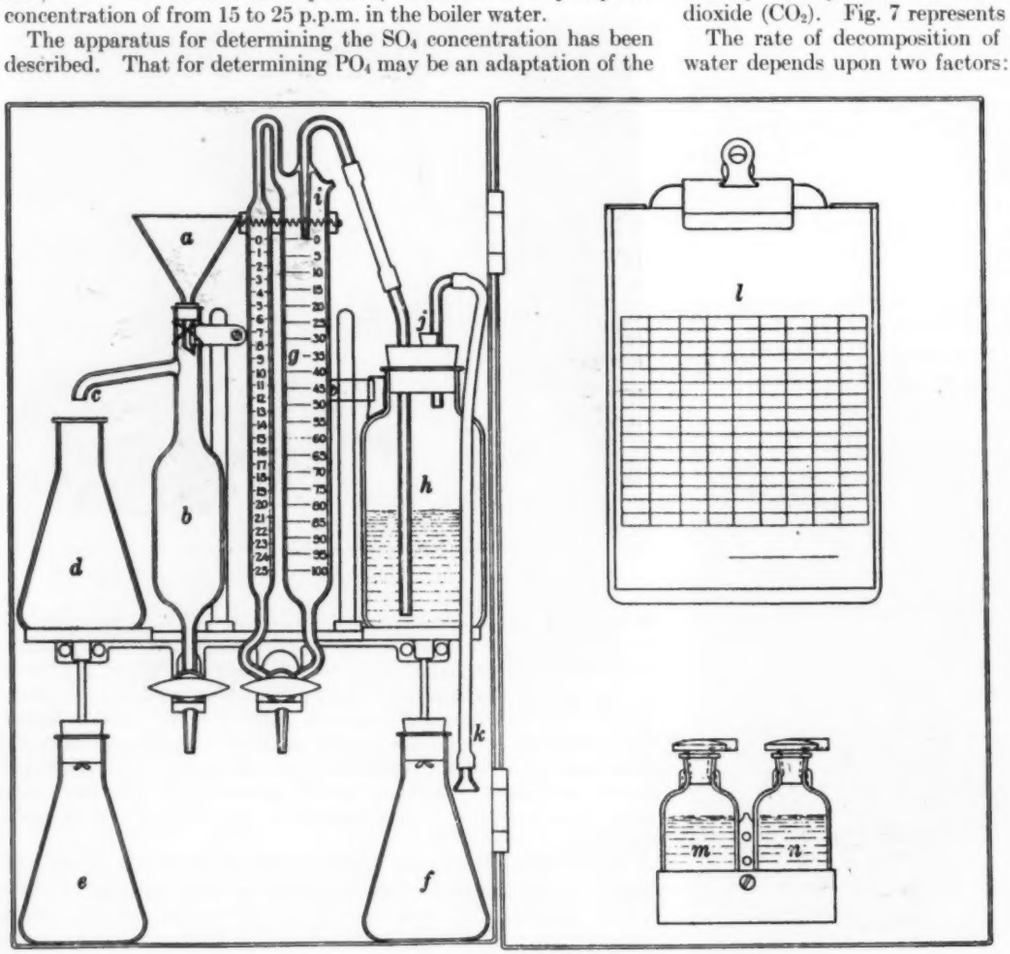

FIG. 6 APPARATUS FOR TESTING ALKALINITY IN BOILER WATERS

cabinet (Fig. 6), or it may be a bulb ending in a capillary tube in which collects the PO_4 precipitated in the determination. Its concentration is then obtained from a graduated scale on the capillary tube by noting the height of the precipitate therein.

THE RELATION BETWEEN CHEMICAL USED IN TREATMENT AND OPERATING PRESSURE

Thus far this discussion has been confined to those conditions in the boiler water whose maintenance is essential for the prevention of scale formation on the evaporating surfaces. We shall now consider the limitations which arise because of high operating pressures.

It is evident from the expression

$$CO_3 > K_2 \text{ (at operating pressure } p) \times SO_4$$

that the maintenance of scale-free conditions depends upon keeping a definite supply of CO_3 in the boiler water. In case conditions arise such that the necessary CO_3 concentration cannot be maintained, then it is no longer feasible to use soda ash as the conditioning chemical.

The decomposition of soda ash at boiler temperatures according to the reaction—

$$Na_2CO_3 + H_2O = 2\ NaOH + CO_2$$

has long been recognized because of the development of caustic alkalinity in the boiler water. Recently Paul[8] and Pollitt[9] have supported the view that the decomposition proceeds in such a manner as to give oxygen and various organic compounds. The premises upon which their conclusions are based are faulty; and thorough examination at the Bureau of Mines laboratory[10] for pressures up to 200 lb. gage has failed to give evidence of any decomposition products other than caustic soda (NaOH) and carbon dioxide (CO_2). Fig. 7 represents a typical decomposition curve.

The rate of decomposition of soda ash dissolved in the boiler water depends upon two factors: (1) the operating pressure, and (2) the rating at which the boiler is operated. These, in conjunction with the concentration of SO_4 in the raw make-up water, and blowdown practice, are the elements that control the feasibility or infeasibility of maintaining the necessary CO_3 concentration. Thus, higher operating pressures are characterized by more rapid decomposition of CO_3 and at the same time by the necessity for maintaining higher CO_3 concentration, since the value of K_1 is greater at higher than at lower operating pressures. In a boiler operating at low rating it may be possible to maintain the necessary amount of CO_3 in the boiler water, while in the same boiler at high rating the more rapid decomposition of CO_3 may render such maintenance impracticable unless the blowdown is of uneconomical proportions. Again, if two boilers are operating at the same pressure and rating, but the feedwater for one is high and the other low in sulphate content, in the boiler receiving the high-sulphate water it may be impossible to maintain the necessarily high CO_3 concentration, even with large blowdown, while in the one receiving the low-sulphate water it may be a simple matter. In fact, it is not essential to examine two boilers to find variations such as those noted; for in a Bigelow-Hornsby boiler with three elements, the author has found[11] a perfect maintenance of the necessary CO_3 concentration in the two cooler elements in which the SO_4 concentration and the amount of steam generated was less than in the third element subjected to the hottest gases; in the latter where clean tube surfaces were most necessary, the higher SO_4 and lower CO_3 permitted a hard scale of calcium sulphate to form.

THE USE OF SODIUM PHOSPHATE

The basic cause for these troublesome limitations in the use of

[8] Paul, J. H., Boiler Chemistry and Feed-Water Supplies. Longmans, Green & Co. (1919), p. 137.

[9] Pollitt, A. A., The Causes and Prevention of Corrosion. Ernest Benn, Ltd., p. 101; ibid., The Technology of Water, Ernest Benn, Ltd. (1924).

[10] Hall, R. E., Robb, J A., and Karch, H. S., Boiler-Water Conditioning and Its Relation to the Non-Condensable Gases in the Steam. Coöperative Bulletin 24, Mining and Metallurgical Series, Carnegie Institute of Technology (1925). In preparation.

[11] Hall, R. E., and Merwin, H. E., Solid Phases Developed in Boiler Waters. Trans. Am. Inst. Chem. Engrs., vol. 16, part II (1924), pp. 91–117.

soda ash lies wholly in its decomposition into caustic soda and carbon dioxide. Also, apart from the uncertainty of maintaining satisfactory CO_3 concentrations, the high caustic alkalinity developed in its decomposition makes it impossible at higher operating pressures to keep within the alkalinity-sulphate ratio recommended in the proposed boiler code[12] as an advisable precaution against caustic embrittlement. As loss of CO_3 by decomposition of the soda ash is a fundamental cause contributing to the difficulties of high-pressure operation, the remedy lies in substituting for CO_3 a substance satisfactory from the standpoint of scale prevention, and entirely stable at the higher operating pressures. We are fortunate in having such a substance in sodium phosphate. It has been one of the most pleasing developments of this investigation to establish the proof that it gives excellent results on the side of scale prevention,[13] and that the total alkalinity necessary in the boiler water with its use can easily be kept well within the limits recommended from the standpoint of caustic embrittlement. The values of K_2 and D in expression (C), given earlier, have been determined, so that conditioning of the boiler water at high operating pressures is as exact as at low pressures.

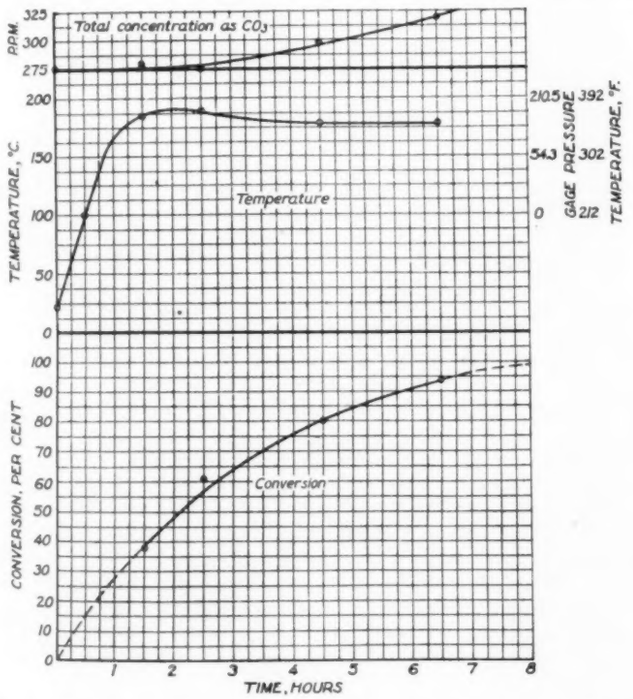

FIG. 7 RATE OF CONVERSION OF SODIUM CARBONATE TO HYDROXIDE UNDER BOILER PRESSURE

Because of the various factors which are effective in rendering the use of soda ash uneconomical or infeasible for the final conditioning of the boiler water, it is impossible to lay down any general rule as to operating pressures and ratings at which the change from soda ash to phosphate must be made. It is doubtful whether the final conditioning with soda ash is economical or feasible at or above an operating pressure of 250 lb. gage. If the make-up water is high in sulphate, or the rating high, the use of phosphate may be necessary at much lower pressures. However, if a copious blowdown with heat exchangers is the practice, soda ash may be satisfactory at higher pressures, though the loss of treating chemical seems unjustifiable.

COMPLETE CONDITIONING FOR HIGH-PRESSURE OPERATION

A satisfactory and practical answer to the complete conditioning of water for high-pressure operation may be given as follows: If the make-up water is evaporated, and the only impure water entering the boiler consists of the condenser leakage, then conditioning the boiler water with phosphate is the only chemical control necessary. If the make-up water is not evaporated, and is of some magnitude, then economy may demand a pretreatment—with lime and soda ash for any water, or by a base-exchange process if the water does not contain temporary hardness—followed by the final conditioning of the boiler water with phosphate. In the pretreatment, however, any addition of excess chemical must be avoided, else detrimental concentrations of caustic alkalinity will develop in the boiler water. If it is deemed desirable to limit the amount of soluble solids in the boiler water, and the feedwater is one that contains sulphate, a variation in pretreatment may be made by using barium carbonate in the softener in place of sodium carbonate, thus removing much of the sulphate as well as the calcium. In any event, however, the final control of the boiler water must be based on the use of a stable substance such as phosphate.

In view of the exactness and simplicity of control which has been developed for the prevention of scale formation on the evaporating surfaces, promiscuous addition of soda ash in the softener, as recently advocated by Behrman,[14] cannot be justified. Although the prevention of scale formation may be attained at the lower operating pressures, this one end is gained at the cost of uneconomical use of chemical and the development of uncontrolled caustic alkalinity in the boiler water, which in turn is a primary factor in causing wet steam and caustic embrittlement. At high operating pressures the rapid decomposition of the soda ash defeats as well the purpose of its use for the elimination of scale formation.

PREVENTION OF SCALE FORMATION ON FEEDWATER LINES AND PREHEATING SECTIONS

The problem of scale prevention on the surfaces that are in contact with water but at which evaporation is not occurring is much simpler than that on the evaporating surfaces as (1) there is only one main constituent in these scales, namely, calcium carbonate ($CaCO_3$); (2) deposition of insoluble scale-forming material occurs by reason of supersaturation throughout the body of the water, and not at the surfaces alone, as in the case where evaporation is occurring; and (3) there is no decomposition of the chemical used in treatment.

In order to prevent scale formation on these surfaces it is necessary either that no bicarbonate (HCO_3) remain in the water—and it is advisable that a small concentration of caustic soda (NaOH) and loose crystals of suspended calcium carbonate be present—or, if bicarbonate be present, that the amount of calcium be very small, or that no decomposition of bicarbonate shall occur. All this may be summed up by stipulating that supersaturation as regards calcium carbonate must be avoided. If the water has been correctly treated externally and sufficient time given for complete reactions to occur, no trouble should be experienced from this type of scale. If, however, this is not the case, the formation of a carbonate scale can be prevented by recirculating water from the boiler through the feed lines or the preheating sections.

This use of the boiler water serves to establish satisfactory conditions for the following reasons: It has been noted heretofore that caustic soda is developed in the boiler water by the decomposition of soda ash, and that the amount in the boiler water at any time must be limited to avoid any danger from caustic embrittlement. It is essential, therefore, to avoid any unnecessary excess of soda ash or caustic in the treated feedwater, because its amount increases to undesirable proportions in the concentrated boiler water. In spite of all precautions in conditioning the boiler water with soda ash, however, some caustic soda is certain to develop. Hence recirculation of the boiler water serves a double purpose: (1) It furnishes the necessary caustic to remove any HCO_3 which may be present in the feedwater and to build up the desirable small concentration of caustic therein; also, its suspended insoluble solids provide the crystals of calcium carbonate mentioned above as advisable, since they hasten the disappearance of any supersaturation. (2) The caustic, by combining with HCO_3 is decreased in amount, and thereby the total caustic concentration in the boiler water is decreased.

In case the final conditioning of the boiler water is done with PO_4,

[12] Suggested Rules for the Care of Power Boilers, MECHANICAL ENGINEERING, vol. 47, May, 1925, p. 371.

[13] Statement by the West Penn Power Company, Serial Report of the Prime Movers Committee, Publication No. 25–68, pp. 8–10 (1925).

[14] Behrman, A. S., Boiler-Feedwater Purification. MECHANICAL ENGINEERING, vol. 47, pp. 909–910 (1925).

on recirculation the reactions are slightly different from those noted above, as the PO_4 combines with calcium in the feedwater. This reaction is advantageous but of small moment, owing to the small quantity of PO_4 in the boiler water.

Hence, whether CO_3 or PO_4 is used in the final conditioning of the boiler water, the prevention of carbonate-scale formation on feed lines and preheating sections depends on the maintenance of the same conditions in the water in contact with them.

THE PREVENTION OF CORROSION ON THE SURFACES IN CONTACT WITH THE FEED OR BOILER WATER

In developing a control of corrosion, phenomena entirely different from those described heretofore must be considered. Thus, Fig. 8 represents diagrammatically a cell in which two strips of boiler steel, identical in composition, are immersed in a solution of sodium sulphate (Na_2SO_4), whose resistance to the passage of the electric

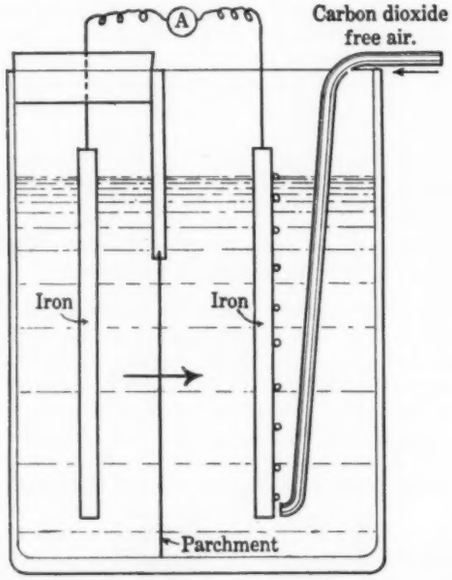

FIG. 8 FLOW OF CURRENT IN AN OXYGEN-CONCENTRATION CELL

current is small. The cell is divided into two compartments by parchment paper, and a stream of air, free from carbon dioxide, is bubbled over the surface of one of the strips. The strips are connected by a metallic conductor, and an ammeter is inserted in the circuit. Evans[15] has shown that under these conditions current flows through the solution between the strips in the direction of the arrow, and that *the strip at which the oxygen concentration is the lesser is the anode, and loses in weight in proportion to the amount of current developed.*

A SIMPLE EXPERIMENT IN CORROSION AND DEPOSITION

The correctness of this conclusion may be demonstrated by a simple experiment which would pay every one interested to perform. It merely consists in placing drops of different salt solutions on a clean surface of boiler metal and watching developments for an hour or so while the drops evaporate at room temperature.

Fig. 9 shows the strips just after solutions of the following composition have been placed upon them[16] (concentrations expressed in parts per million).

Upper Row of Drops

	Strip Number			
	1	2	3	4
Na_2SO_4	Distilled Water	740	0	370
NaCl		0	825	412
NaOH		0	0	0

Lower Row of Drops

	Strip Numbers			
	1	2	3	4
Na_2SO_4	Distilled water	740	0	370
NaCl	+	0	825	412
NaOH	1175	1175	1175	1175

The time (minutes) which had elapsed when the photographs illustrating this experiment were taken is as follows:

Fig.	9	10	11	12	13	14
Time, min.	0(*a*)	10	27	40	70(*b*)	−(*c*)

(*a*) It required probably a couple of minutes to place the drops on the strips as they lay in position.
(*b*) Evaporation was complete.
(*c*) The samples had been wiped off with a damp cloth.

On account of their depth it is practically impossible to eliminate all shadows in the drops at the start, but as evaporation proceeds, and the depth lessens, they disappear. The deposits forming are so definite in outline, however, that there is no possibility of confusing shadow and deposit at any stage.

Strips 3 and 4 of Fig. 9 show the rapidity with which corrosive action begins in salt solutions. The photograph was taken as quickly as possible, yet there are visible the first shadowy outlines of the deposits so definitely portrayed in the other photographs.

As corrosion proceeds, a shell of clear solution covers the entire exterior of the drop, while the interior is just as definitely filled with a dense precipitate which continues to grow more dense as time passes (note especially Figs. 10 to 12).

THEORY OF FORMATION OF DEPOSIT

Evans' explanation for the formation of the dark deposit is as follows: When the drops are first placed on the metal, any dissolved oxygen is uniformly distributed through them. In contact with the metal, however, this oxygen, which is necessarily small in quantity and negligible in its effect on the metal surface, unites with it. On the exterior surface of the drop the air in contact furnishes a supply of oxygen, and the concentration of that in solution does not diminish materially. In the interior, however, this is not the case, and a deficiency in oxygen exists.

Thus a condition has developed which is precisely that of the cell in Fig. 8. The metal in contact with the interior portions of the drop has become anode, and will dissolve (corrode); the exterior portions are cathodic, hence do not corrode. In the interior, the dissolved metal is in the ferrous state, as evidenced by the almost white color of the hydroxide which first forms. As it comes in contact with oxygen diffusing from the outer layer, it becomes blue and finally assumes the reddish yellow color of ferric oxide. Corrosion has occurred freely, whether the drop consisted of distilled water, or contained sodium sulphate or chloride. It is significant that the clear outer shell should be of much less thickness in the drop containing distilled water (No. 1), and a sharp heavy line of deposit should mark the boundary between outer and inner shell in all the drops. The former is in accord with the fact that the electrical resistance of distilled water is much greater than that of the salt solutions; and the latter illustrates the condition so uniformly found wherever corrosion occurs at a water-air interface, that the most severe attack on the metal occurs just below the water line.

When evaporation is complete as shown in Fig. 13, the difference between the soluble material in the clear outer shell of the drop and the corrosion deposit in the inner shell can be clearly distinguished by the white color of the material that deposits from solution as the outer shell evaporates, and forms a complete ring about the dark corrosion deposit. When the metal surface is rubbed with a damp cloth, as in Fig. 14, and all water-soluble material is removed, it is evident that the substance formed by evaporation of the outer shell has been removed, and leaves no trace of corrosive action on the metal surface.

Figs. 15 and 16 are typical examples of corrosion caused by differences of oxygen concentration.

THE EFFECT OF HYDROXIDE

In the lower series of drops identical in composition with the upper series, save for the addition of caustic soda, no corrosion is evi-

[15] Evans, U. R., The Corrosion of Metals. Edward Arnold & Co. London (1924), pp. 72–77.

[16] The author wishes to acknowledge the valued assistance of E. A. Hertzell, Fellow, Carnegie Inst. of Technology, and G. H. Henneman, photographer, Bureau of Mines, in obtaining these photographs; also to acknowledge the courtesy of F. N. Speller, metallurgical engineer, National Tube Co., in furnishing the boiler tube from which the strips were made.

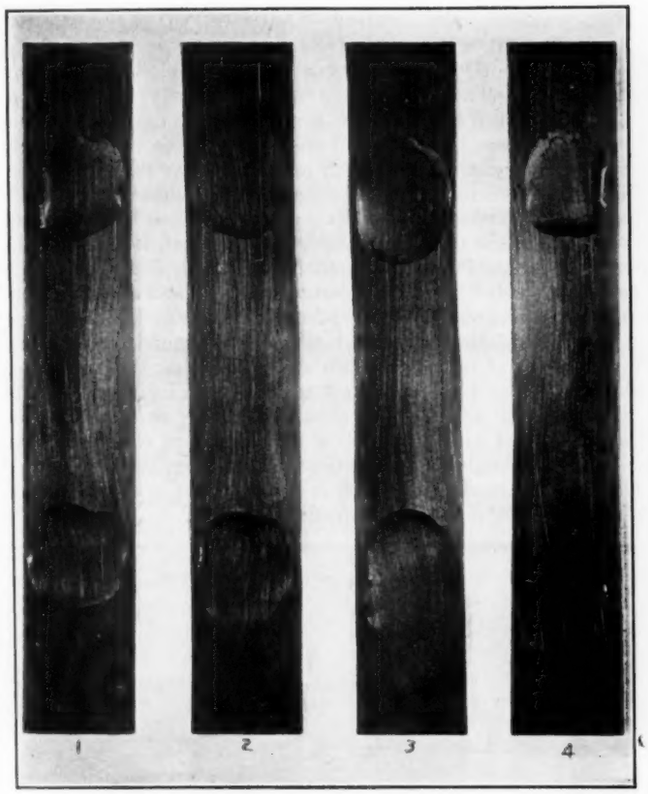

FIG. 9 THE OCCURRENCE OF CORROSION AT THE POINT OF LESSER OXYGEN CONCENTRATION—START OF EXPERIMENT

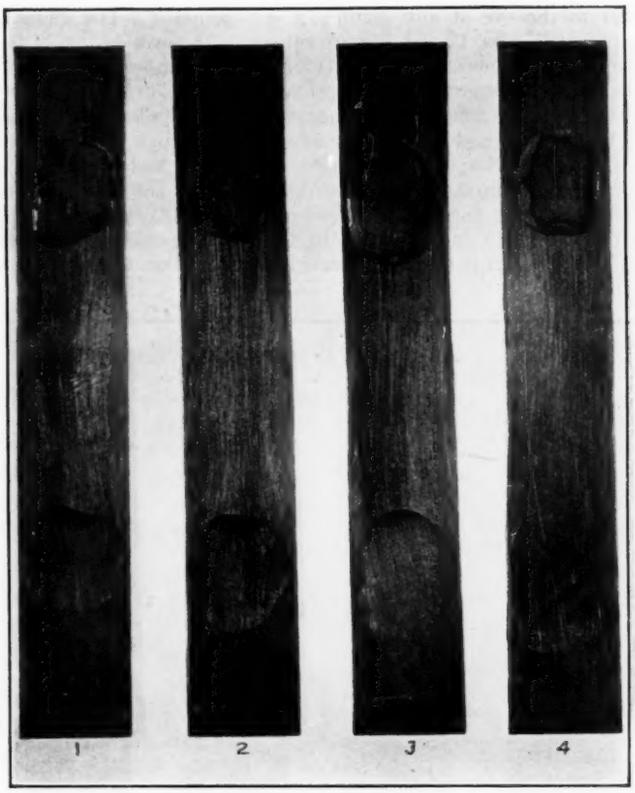

FIG. 10 CONDITION OF STRIPS OF FIG. 9 TEN MINUTES AFTER START OF EXPERIMENT

(Referring to Fig. 9, even the short time that elapsed between arranging the drops and photographing them was sufficient for action to start in the upper series.)

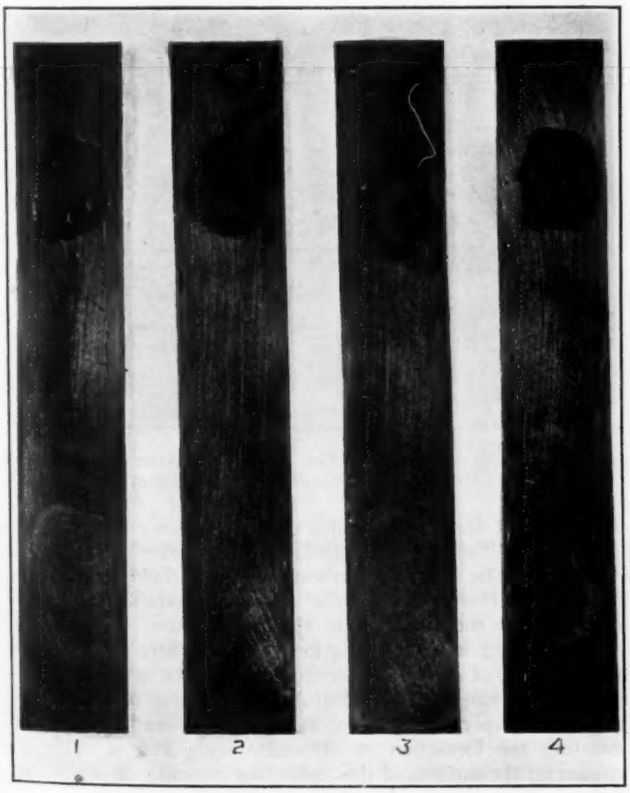

FIG. 11 CONDITION OF STRIPS 27 MINUTES AFTER START OF EXPERIMENT

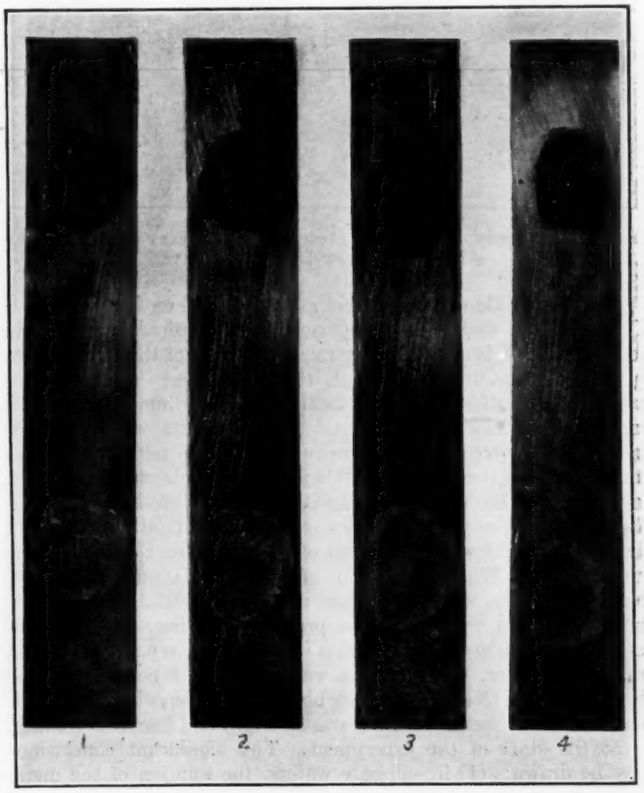

FIG. 12 CONDITION OF STRIPS 40 MINUTES AFTER START OF EXPERIMENT

dent to the eye at any point of the experiment. The deposits apparent in Figs. 12 and 13 were caused by the evaporation of the drops, and disappeared entirely (Fig. 14) when rubbed with a damp cloth, leaving scarcely a perceptible stain on the metal surface. The chance for difference in concentration of the dissolved oxygen in the exterior and interior portions of any drop was as great as in the upper series; yet corrosion was inhibited. And as the caustic soda (NaOH) in the lower series of drops was the only point of difference from the upper series—more particularly because the hydroxide (OH) concentration in the lower represented the only difference—then it must be specific in its inhibition of corrosion of boiler steel.

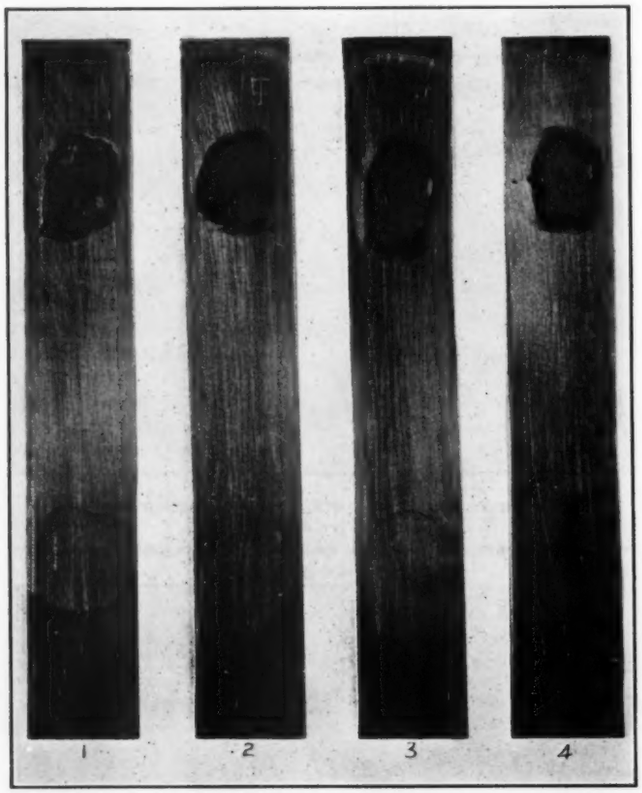

FIG. 13 CONDITION OF STRIPS 70 MINUTES AFTER START OF EXPERIMENT —EVAPORATION OF DROPS COMPLETE

That hydroxide can be specific in inhibiting loss from an anode of boiler steel, and that the concentration required is subject to definite control, is illustrated by the appearance of the strips shown in Fig. 17. In this experiment, the boiler steel, as anode, was rotated in a solution containing 2950 p.p.m. of sodium sulphate, and varying quantities of caustic soda. A platinum wire served as cathode. A current of low density (0.002 amp. per sq. cm.) was passed through the solution. When no hydroxide was present the corrosion was uniform (No. 5, with corrosion product adhering; No. 4, after deposit had been cleaned off with a bristle brush), and the loss in weight was 95 per cent of theoretical on the basis of the current used. When 940 p.p.m. of caustic soda was present the loss by corrosion was 87 per cent of the theoretical and was not uniform (No. 3 with corrosion product adhering; No. 2, after scrubbing with a bristle brush). With 2350 p.p.m. of NaOH present, however, the corrosion was less than 1 per cent of the theoretical loss (No. 1, on which no corrosion deposit was in evidence), and the metallic surface was as bright and free from coating, as at the start of the experiment. Two significant conclusions may be drawn: (1) in sulphate waters, the solution of the metal in anodic areas may be practically inhibited by the presence of sufficient hydroxide in the water (strip No. 1); (2) insufficient treatment with hydroxide results in localizing corrosion effects without materially decreasing their rate (strips Nos. 2 and 3), and emphasizes the need for sufficient hydroxide to protect the weakest spot of the anodic area.

THE CONTROL OF CORROSION

In general, it seems quite certain that any corrosion of the boiler-system surfaces in contact with water is electrochemical in character. Anodic conditions in the metal may develop from differential oxygen concentration, especially in feed lines and economizer tubes, from impurities in contact with the metal (as mill scale), or from a state of strain or local differences of temperature. The control of corrosion therefore signifies, so conditioning the water that at any anodes which may develop, passage of current generated results not in the dissolution of the boiler metal, but in the discharge at the anode of some component in the boiler water. It is the author's belief based on experimental work and operating control now in progress (1) that hydroxide is specific in this respect as regards sulphate waters, and satisfactorily inhibitive for practical purposes as regards chloride waters; (2) that the control for inhibition of corrosion is as exact as that given for elimination of scale formation; and (3) that even in the extreme case of a raw water saturated with air corrosion of feed line or economizer can be reduced to negligible proportions. It is essential, however, as shown by the results illustrated in Fig. 17, that a well-controlled sufficient concentration of hydroxide be present.

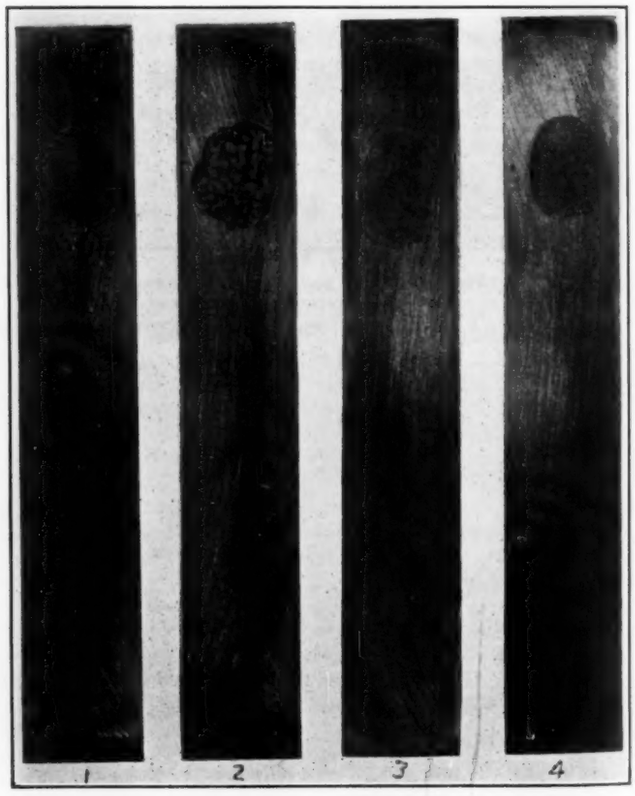

FIG. 14 SURFACES OF STRIPS OF FIG. 13 AFTER HAVING BEEN RUBBED WITH A DAMP CLOTH AND ALL WATER-SOLUBLE MATERIAL REMOVED

It is evident that maintenance of the necessary concentration of hydroxide at the preheating surfaces of the boiler by continuous addition of caustic to the system would result in building impossible concentrations thereof in the boiler water. By establishing a satisfactory caustic concentration in the boiler water, however, and then distributing it by recirculation to the surfaces in the system where it can be of service, the desired ends can be attained. Thus the caustic developed in the control for prevention of scale formation on the evaporating surfaces may serve the double purpose of preventing the formation of carbonate scale and of inhibiting corrosion on the surfaces of the preheating system.

CONTROL OF NON-CONDENSABLE GASES IN THE STEAM BY CONDITIONING THE BOILER WATER

When pure water makes contact with boiler steel under the conditions characteristic of boiler water, slight chemical reaction occurs, and a small amount of hydrogen gas is generated. This forms

FIG. 15 CORROSION OF A NIPPLE IN THE FEEDWATER-INLET LINE CLOSE TO THE BOILER

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If the feedwater contains dissolved air, much of this is removed in the feedwater heater or the deaerator. A little passes to the boiler, however, and thus the steam contains trifling amounts of nitrogen, oxygen, and carbon dioxide.

By decomposition, as illustrated for sodium carbonate, carbonates of any kind (sodium, calcium, magnesium, barium, etc.) in the boiler water give a source of carbon dioxide gas, so that its quantity in the steam may no longer be negligible for many uses of the steam. Thus the concentration may be undesirable if the steam is to be used for process work; and it is certainly a liability to the central station whose steam is used for heating purposes. This follows because of the corrosion it may stimulate wherever condensation occurs in the system.

FIG. 16 CORROSION IN A TUBE IN THE PREHEATING ELEMENT OF A BIGELOW-HORNSBY BOILER

Wherever the presence of carbon dioxide in the steam is detrimental, the obvious thing to do is to keep all carbonates, so far as possible, from the boiler water. If the make-up water is evaporated, direct control of the boiler water with PO_4 limits the quantity of carbon dioxide to the amount derived from condenser leakage. If the feedwater is given a primary treatment with lime and soda ash, it is necessary to avoid all excess of treatment, and use a secondary control with PO_4 on the boiler water. If the feedwater contains temporary hardness and is treated by a base-exchange process, it may be necessary to pretreat with lime, or to remove the excess sodium bicarbonate in the water after treatment by the use of acids or other means, and the final control must be established on the boiler-water by means of PO_4.

In general, wherever the uses of the steam are such that a minimum of non-condensable gases is permissible therein, each step of the water-conditioning process must be carried out with the object of eliminating such gases as far as possible; and the final conditioning of the boiler water must be done with a chemical which does not decompose at the operating pressures in question.

OTHER FACTORS IN BOILER-WATER CONDITIONING

The control of sludges and soluble salts in the boiler water and its relation to wet steam, and the removal of any boiler water and its suspended insoluble material from the steam are as integral parts of any complete system of boiler-water conditioning as those factors which have been considered already. It was the purpose of this paper, however, to present those features of such a system in which the Bureau of Mines has actively coöperated. This has been done, therefore this discussion need not be carried further.[18]

In this research covering a period of four years, it is impossible adequately to recognize the achievements of all those associated in the development; but the author takes pleasure in ascribing any success attained to the unstinted support he has been given by A. C. Fieldner, chief chemist of the Bureau of Mines, and J. M. Hopwood, president of the Hagan Corporation, and their respective organizations.

Discussion

J. D. YODER[19] submitted a written discussion of Dr. Hall's paper in which he said that one important conclusion reached by the author was that scale formed by direct deposition, or as he

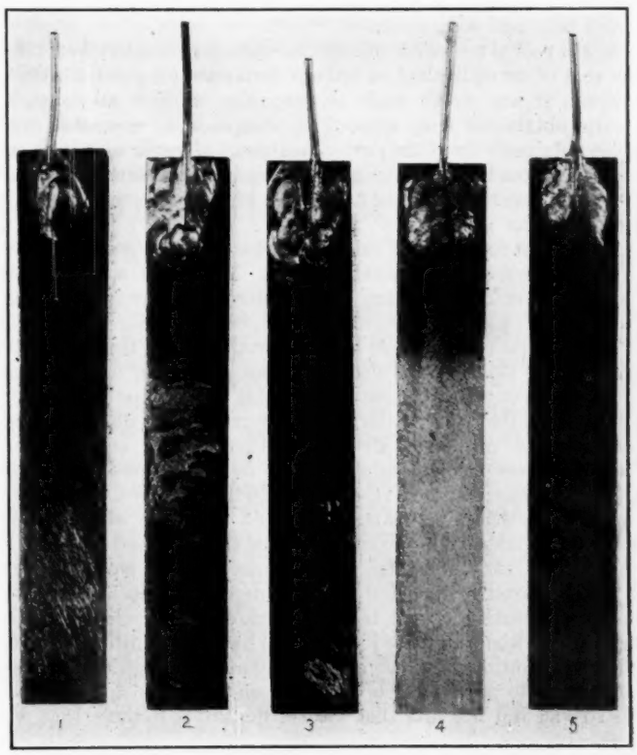

FIG. 17 CORROSION OF BOILER STEEL BY ELECTRIC CURRENT OF LOW DENSITY WHEN THE SOLUTION IN CONTACT CONTAINED SODIUM SULPHATE AND VARYING CONCENTRATIONS OF SODIUM HYDROXIDE

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[19] In charge of Water Purification Department, Cochrane Corporation, Philadelphia, Pa. Mem. A.S.M.E.

dent to the eye at any point of the experiment. The deposits apparent in Figs. 12 and 13 were caused by the evaporation of the drops, and disappeared entirely (Fig. 14) when rubbed with a damp cloth, leaving scarcely a perceptible stain on the metal surface. The chance for difference in concentration of the dissolved oxygen in the exterior and interior portions of any drop was as great as in the upper series; yet corrosion was inhibited. And as the caustic soda (NaOH) in the lower series of drops was the only point of difference from the upper series—more particularly because the hydroxide (OH) concentration in the lower represented the only difference—then it must be specific in its inhibition of corrosion of boiler steel.

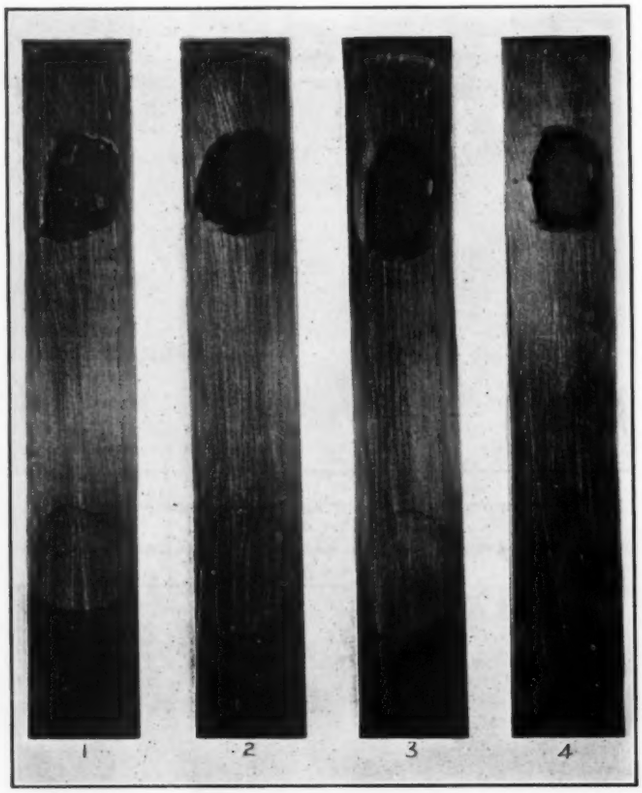

Fig. 13 Condition of Strips 70 Minutes after Start of Experiment —Evaporation of Drops Complete

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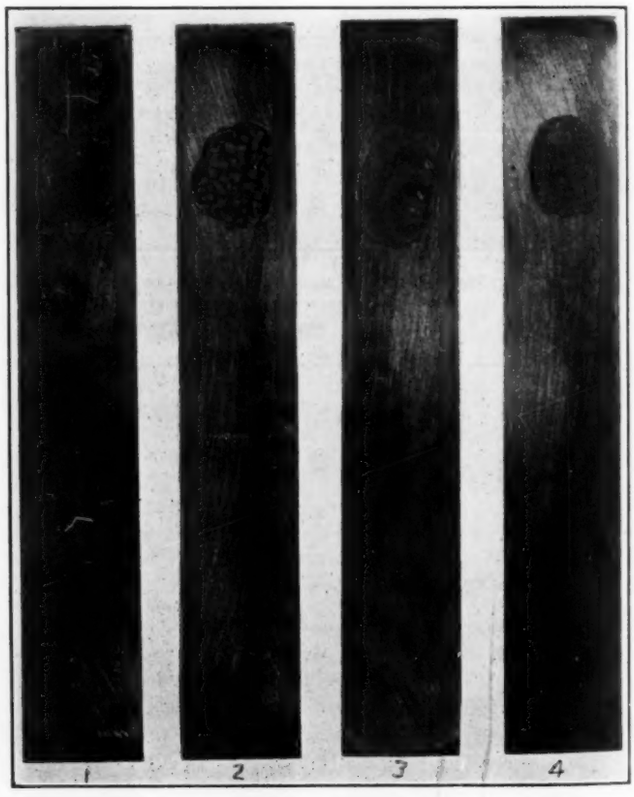

Fig. 14 Surfaces of Strips of Fig. 13 after Having Been Rubbed with a Damp Cloth and All Water-Soluble Material Removed

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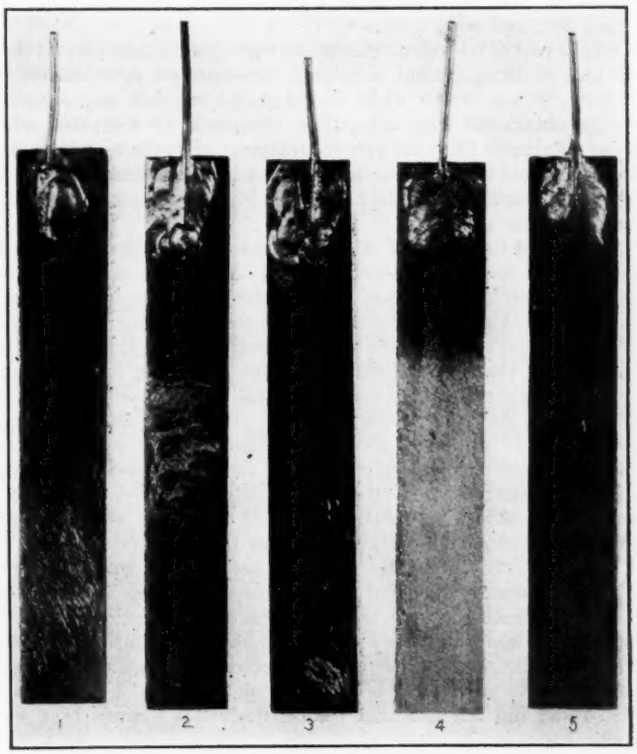

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termed it, *in situ*, and that it did not represent two distinct steps: first, the formation of insoluble precipitates, and second, the baking or attachment of these to the tubes.

This conclusion was at variance with claims that had been made for boiler skimmers of various types, including boiler-water filters through which a portion of the boiler water was circulated for the purpose of removing suspended solids. Filters for this service had sometimes been termed "deconcentrators," but this term was inaccurate in that filters did not lower the concentration of solids in solution; they removed suspended matter only. Claims had repeatedly been made that these skimmers and boiler-water filters would protect boilers from scale without chemical treatment, but such claims had never been taken seriously by experienced water-purification engineers.

It was a pleasure to observe that the author had come to the conclusion that "if the make-up water is not evaporated and is of some magnitude then economy demands the pretreatment with lime and soda ash for any water or by a base-exchange process, if the water is not high in temporary hardness." He desired, however, to supplement this treatment by feeding a quantity of tri-sodium phosphate to the boiler, instead of feeding an excess of sodium carbonate, as was commonly done when using lime and soda softeners. He recommended the use of tri-sodium phosphate to supplement external treatment, particularly for high boiler pressures. His argument that tri-sodium phosphate did not break up in the boiler to form sodium hydrate, at least to the same extent as sodium carbonate, was well taken, although Mr. Yoder would like to inquire if Dr. Hall did not believe that there would be a chemical reaction between tri-sodium phosphate and calcium carbonate to form sodium carbonate and that the latter would break down into sodium hydrate and carbon dioxide, just as a small excess of sodium carbonate would do if the water were completely softened in an external lime and soda softener.

As the cost of tri-sodium phosphate was approximately four times the cost of its equivalent of sodium carbonate for precipitation of calcium, it was worth while to determine whether any superior results obtainable from tri-sodium phosphate as compared with those obtainable from the proper treatment of water with lime and soda ash would justify the more expensive tri-sodium phosphate treatment together with the added cost of the equipment necessary for its feeding.

To prevent formation of calcium sulphate scale by water softened in a hot-process lime-and-soda softener, Mr. Yoder wrote that he had never found it necessary to feed more than one to two grains (average $1^1/_2$ grains) excess sodium carbonate; and for waters quite low in mineral solids, where high concentrations in the boiler were permissible, this average excess sodium carbonate had been reduced to a considerably lower figure; this to maintain a maximum alkalinity in the boiler of thirty to forty grains per gallon, including hydrate and carbonate alkalinity. Under these conditions he had never seen calcium sulphate scale formation, and it was rare that the excess sodium carbonate alkalinity required for the prevention of calcium sulphate scale would not come within the alkalinity-sulphate ratio recommended in the proposed code of the A.S.M.E. Code Committee as insurance against embrittlement. For this reason it appeared that the need for supplementing the lime-soda treatment with tri-sodium phosphate would seldom be found. He would be more interested in having the author state the limiting conditions for prevention of calcium silicate scale. Whereas he referred to prevention of calcium silicate scale in the paper, Mr. Yoder did not find that he had derived a formula that was applicable.

The author, wrote Mr. Yoder, concluded that calcium sulphate scale formed on the tubes because calcium sulphate became increasingly insoluble with high temperatures and that scale was prevented where water was treated with sodium carbonate because the calcium carbonate became very slightly more soluble at higher temperatures. This thought was ingenious, but it was not conclusive and, furthermore, was difficult to reconcile with practical experience. In support of this conclusion the fact was advanced that calcium carbonate scale formed on the feed lines, the occurrence of which the author believed was due to the surface of the pipe through loss of radiation having a slightly lower temperature than the water.

Mr. Yoder felt that it would be desirable for the author to explain how he fitted into this theory the fact that if a sulphate water was not given pretreatment or internal treatment with soda ash, calcium sulphate not only formed on the boiler tubes but also on the stay bolts and handhole caps of boiler headers. The latter were obviously of slightly lower temperature than the water because of heat loss by radiation. Again, how would the author explain the formation of calcium carbonate scale on economizer tubes and the tubes of closed feedwater heaters or trays of open feedwater heaters as well as on the boiler feed line itself? Might not the more logical, or at least the more practical, explanation of the formation of scale be that as solids were removed from solutions that become supersaturated as a result either of heating alone, as in feedwater heaters and economizers, or by heating and evaporation, as in boilers, these crystals tended to deposit on any surfaces over which the water was passed and that in so depositing the crystals adhered to the surfaces and finally to the crystals, i.e., in such a manner as might be termed a growth of these crystals?

The question as to just what theory should be accepted in explanation of the formation of scale in boilers was somewhat academic and of little importance compared with the knowledge that by proper chemical treatment scale formation could be prevented, and concerning this all water-purification engineers were probably in agreement with Dr. Hall that proper treatment of the water with lime and soda ash would prevent scale formation.

A. S. Behrman[20] wrote that he desired to bring out the fact that practically all of the conditions which the author stated were essential for successful boiler-water conditioning were logically met and had been met for years by the lime-soda and zeolite methods of exterior treatment, even though the practice of these methods might have been developed to a greater or less extent empirically. The unfavorable conditions in the boiler water which the author had described so interestingly, and for the correction of which he had worked out control methods based on physical-chemical considerations, either did not exist in the boiler water or were automatically taken care of, in the great majority of cases, if the water was properly treated before it entered the boiler.

In speaking of scale prevention, it was important to distinguish between the two kinds of hardness in water and the different chemical treatments required. Temporary, or carbonate, hardness could be removed bodily from water by precipitation without leaving any dissolved solids in exchange. The precipitation might be accomplished by long-continued boiling with ample escape for the gases liberated; or it might be effected very quickly and cheaply by the use of lime. Permanent hardness, due to calcium and magnesium sulphates and chlorides, could be removed chemically, but a corresponding amount of sodium sulphate and sodium chloride was left in the water as a result of the treatment with soda ash or other precipitant. In either case, a considerable amount of sludge was formed, the amount varying of course with the hardness of the water.

If the water contained excessive amounts of temporary hardness, as did many waters in the Middle West, notably the ground waters of Illinois, lime-soda softening was in general to be preferred. As a result of this treatment, the sludge and scale-forming materials, frequently amounting to 2 or 3 lb. per 1000 gal., were removed from the water before it went to the boiler. Furthermore, it was standard practice and had been for years, to leave in the treated water an excess of one to two grains per gallon—or even more in some cases—of soda ash, which in nearly all usable waters provided the excess of carbonate over sulphate which the author stated was necessary to prevent the formation of scale.

With waters containing permanent hardness, and with little temporary hardness, there could be little question that zeolite softening was the preferred method as far as scale prevention was concerned. Modern zeolite softeners, properly operated, would deliver water of zero hardness; and if there was no calcium or magnesium in the water entering the boiler, the excess carbonate over sulphate ratio mentioned by the author had, of course, no significance.

It had been shown pretty definitely that foaming generally resulted from a combination of suspended matter and of soluble salt concentration; and that in the absence of either one of these

[20] Chief Chemist, International Filter Co., Chicago, Ill.

factors, the effect of the other was minimized—that was, that relatively high concentrations could be carried in the absence of suspended matter, and that only low concentrations could be carried in the presence of appreciable amounts of suspended matter. This was, of course, a strong argument for exterior treatment as against internal treatment with soda ash or other precipitating agents. Mr. Behrman did not include in this category such internal treatment as that with modified castor-oil compounds to reduce foaming.

It had been the practice for a good many years in a number of plants equipped with lime-soda softeners to overtreat the water in order to take care of contaminated returns which went to the boiler without treatment. Furthermore, the practice was becoming increasingly popular to use zeolite-softened water for cooling purposes, to prevent scaling of condensers. In these cases, of course, condenser leakage could not contribute to boiler-scale formation.

His company had no case on record of boiler corrosion where the boiler water had been properly softened by the hot-process lime-soda method. He could speak authoritatively, of course, only of his own company's experience; but he had no doubt that other manufacturers could present the same record.

As to caustic embrittlement, a sub-committee of the American Water Works Association and coöperating societies had recently been appointed to study the question. This Committee's work was not going to be easy. Just one indication of this was the statement attributed to Dr. Jacobus, consulting engineer of the Babcock & Wilcox Company, that he had never seen a case of caustic embrittlement with zeolite-softened water, in spite of the soda that it might contain.

The author, in closing said that the status at the Bureau was purely that of investigating underlying fundamental conditions. It did not consist in standing forth for any definite sort of equipment—that was for the engineer to choose. The chemical conditioning was fundamentally a thing which was based upon the solid phase which could deposit at the boiler surfaces, and despite the fact that such practice had been followed, according to Mr. Behrman's statement, for a great many years, the author thought he was familiar enough with the literature of water softening, patent and otherwise, to say that in the 80 years that had passed since Melville's patent in 1838 and Clark's patent in 1841, there had never been any definite written consideration given to the fixing of the solid phase which would separate at the evaporating surfaces.

One thing that the Bureau had injected into this consideration which had not been there before, was definite control of the concentrations which would produce the desired results, which therefore put the introduction of chemical on to an economic rather than a chance basis.

In the second place, recognition of the effect of carbonate in determining that concentration, recognition of the fact that its decomposition allowed the equilibria to change in the boiler so that a standard softened water going to the boiler might, in the process of concentration, lay down a very nice and hard silicate or sulphate scale—a recognition of that, and the substitution of an unchanging radical for the carbonate, were essentially new things in the water-treating problem.

In regard to corrosion, he had pointed out that the question of putting alkali in to stop corrosion could be rather a boomerang, because if the weakest point in the metal was not being protected it was being subjected to the action of the water and corrosion. Hence, a definition of the alkali in contact with that metal to obviate corrosion was necessary.

As to experience with sodium phosphate working up to 600 lb. pressure in the new plants, about which Mr. Behrman had inquired, he would say that the sodium phosphate had been in active operation on 350 lb. pressure for almost two years now, and for application to 600 lb. it would mean a few degrees of change. Where working under an alkaline condition of about 100 parts per million the tricalcic phosphate would be maintained—it would not change its condition.

Variety Through Standardization

By C. E. SKINNER,[1] PITTSBURGH, PA.

THE snowflake, one of the most beautiful objects in nature, adheres in its formation to an exceedingly simple standard structure, and yet no two snowflakes among the tens of thousands that have been studied have ever been found to be exactly alike. This standard consists of six lines radiating from a common point and forming 60-deg. angles, with the further proviso that any extension of the structure shall form a 60-deg. angle with the main arm or with the arm from which it grows. A growth at a point on any arm is exactly duplicated by a similar growth on all of the other arms. The angles are always 60 deg., no more and no less. This simple example shows that it is possible to produce an infinite variety of forms, each of which conforms to a very simple and exact fundamental standard. In all her departments, nature follows standards to such an exact degree that the measurement of an angle of a mineral crystal, for example, may often serve to absolutely identify the mineral. The discovery of a single fossil bone is often sufficient to permit the expert to reconstruct the prehistoric animal and tell something of its habits of life. If it were not for nature's standards, such sciences as astronomy, chemistry, and physics would be impossible.

Nature's Use of Standards

Furthermore, when nature desired quantity or mass production, she invariably used standards, such as swarms of mosquitos, or grasshoppers or other noxious insects. The very fact that the life history of the mosquito conforms to an absolute standard, makes it possible for man to provide standard methods for their mitigation. Perhaps in no field does nature follow a more rigid standard than in the form and life history of the insect world. So rigid are the standards of performance in insects that they have no adaptability to changed conditions. Fabre has proved this again and again in his fascinating studies of insect life. We say that this standard performance is due to instinct, and we stand amazed both at its wisdom and at its stupidity. The human body conforms to a standard so exact that any major variation such as an extra finger or a slightly misplaced heart is called a freak. We all have the same frame, the same nervous system, and the same circulatory system to such a degree of exactness that the surgeon knows just where to look for the useless appendix or the troublesome thyroid gland. This standardization of the human body—alike in all races—makes modern surgery possible. Yet we marvel when we find two persons so alike that we cannot tell them apart. Proper standardization is therefore no bar to infinite variety.

Nature advances with exceeding slowness by trying experiments, producing forms different from the standard which are known as freaks or variants. If the variation is a success, a new order or a new species may be developed, but if a failure, the variant perishes. Contrary to nature's methods, man usually enters a given field by the production of a very large number of variants, and then gradually tends to standardize when the most satisfactory form or construction is determined upon and quantity production becomes desirable. In the early days of the bicycle craze, one could tell the make by a glance at the form of the frame. Later the frame construction of all makers came so closely to a general standard that they were all essentially the same.

[1] Assistant Director of Engineering, Westinghouse Electric & Manufacturing Co.; Chairman American Engineering Standards Committee.

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STANDARDIZATION LARGELY A PRODUCT OF OUR INDUSTRIAL AGE

Standardization in human affairs is largely a product of our industrial age. In former days when each family or each small group produced its own goods there was little or no need for industrial standards. As we began to assign to one special group the production of a given commodity and to another a different one, the necessity for standards at once became apparent. If the maker of a machine, for example, made all his own screws and bolts and his product was used only in a restricted area so that he could look after replacements and repairs, no standards of screws and bolts were really necessary. When, however, his product was used over a wide area, standards for replacable parts became essential. As our specialization in industry has grown, both the necessity for standards and the difficulty of their accomplishment and use have multiplied.

It is interesting to trace the usual course which a typical industry follows, and which finally results in the establishment of standards for that industry. Beginning, perhaps in a small way, each manufacturer adopts certain materials, processes, and constructions for his own use, with little or no attempt to harmonize them with others, either in his own or allied lines of production. When quantity production begins, it becomes desirable to use as many standard materials and purchased parts as possible, and it also becomes desirable to harmonize his devices or product with others of a similar nature to meet the general requirements of the market, especially when the device or product becomes a part of an assembly to make a complete whole, as, for example, a motor and a machine tool.

AN EXACT evaluation of the benefits which have already accrued to American industry through the standards programs which have been carried on in its various branches is impossible, but it can be confidently stated that without these programs the industries could not have satisfactorily advanced. Neither can the value of future work along this line be predicted accurately in dollars and cents. It must be evident, however, that an ever-increasing program of simplification and standardization must be carried on to equalize our ever-increasing tendency to complexity of methods, products, and devices, and to stem the ever-rising tide of cost of living and to provide more recognized products which can be purchased with confidence that they will conform to known qualities and performances. We are very sure that the cost of engineering standardization is but a very small item compared to the benefits which through its application accrue to our people as a whole.

There are, also, usually certain fundamental characteristics, principles, and measurements which must be established as a part of the business in order to deal intelligently with the producers of the raw materials and with users of the product. The units of measurement are either assumed as the general standard, or must be specified, as the foot or the meter; the general process of manufacture is often mentioned, such as the bessemer or open hearth, in steel making. The basis of rating is often required, as the temperature limits for electrical machinery or the code on which boilers are purchased. Installation work is often called for in accordance with some standard requirements, such as the National Electrical Code or the National Electric Safety Code. The producer therefore finds it desirable to join forces with other groups engaged in the same general line of business with a view of harmonizing and standardizing those things which are of mutural interest. The consumer buying from various producers finds standards necessary, both on account of arriving at a comparison and for purposes of interchangeability.

THE ELECTRICAL INDUSTRY AN EXCELLENT ILLUSTRATION OF THE VALUE OF STANDARDIZATION

The electrical industry affords an excellent illustration along this line. The materials of construction used in electrical machinery and apparatus are perhaps more varied than those required in any other industry, and the products of the electrical manufacturers are now applied to almost every other industry in the world today. The requirements for manufactured parts in this industry, such as, for example, screws, bolts, and nuts, cover the whole range from those required by the watchmaker to those required by the manufacturers of the largest machinery built. Finishes of many grades, varnishes paints, and impregnating compounds form an essential part of the product. Perhaps no other industry uses such a wide variety of metals, which are required for purposes of strength, magnetic characteristics, conductivity, resistance, decorative, and other purposes. Its products are used in every possible connection from the winding of clocks and lighting of buildings and streets to the driving of ships and steel mills and hauling of passenger and freight trains. Every change in material, process, or product therefore requires a corresponding change in some other industry. This at once illustrates the desirability of standardization and the difficulties which attend its accomplishment. It shows the necessity of the electrical industry's utilizing standard materials in its manufactured products, standard processes in factory operations, and in arriving at mutually satisfactory standards with the thousand and one industries which utilize its products. This is particularly true in connection with those parts which are subject to replacement due to wear, and those parts, such as screws, nuts, and bolts, which are involved in case of repair. Standards for those dimensions which are to "line up" with apparatus with which they form a part of a completed whole are of prime necessity. It is evident that standard methods of rating and methods of specifying tests and performance must be arrived at if there is to be intelligent understanding between the manufacturer and user of these devices. In addition to all this, the electrical industry has been developing with phenomenal rapidity, and it has not been possible for manufacturers to retain any given device or construction for more than a few years at best without more or less complete redesign to meet new requirements, to provide application in new fields, to utilize the discovery of new principles, or to meet the ever-present keen competition. The electrical industry, like many others, early undertook the work of standardization in its own field, and in spite of all these handicaps perhaps no other industry has carried standardization farther and with more benefit to material supplier, manufacturer, distributer, and user.

This standardization work has been carried on almost continuously ever since the beginning of the electrical industry, and at no time has the work been more active than at the present, and at no time have there been more important problems ahead needing attention. The standardization already accomplished has been one of the major factors in promoting the rapid development of the industry and in bringing to its present state of perfection. It is recognized, however, that for its continued prosperity, standardization work must continue so long as the industry develops and changes are necessary.

WORK ALREADY DONE IN INDUSTRIAL STANDARDIZATION

Each industry's standardization program has its own problems and difficulties, and in each this work is of increasing importance. The industry must not be hampered in its development by its standards, and on the other hand it must not be so out of line with other industries that it cannot meet them on common ground for their mutual benefit, whether this be the producers of its raw materials, its competitors, or the users of its products.

The great national engineering societies have naturally been the leaders in bringing about the basic understandings and standards, because of their independent position and freedom from bias due to self-interest. Trade associations have generally found a program of standardization to be one of the most fertile sources of benefit to their members. Engineering societies, trade associations, and other groups who have engaged in this work have soon found that there were desirable points of contact in their work with the work of other groups, and in many cases there are parallel or overlapping points of interest.

Much progress has been made in many fields such as the automotive, electrical, mechanical, chemical, textile, and others. The American Society for Testing Materials has done a most notable work in promulgating standard specifications for the purchase and testing of materials of many classes. The Bureau of Standards has long been engaged in the determination of our fundamental standards of weights and measures, and more recently the Federal Specifications Board has undertaken to promote standard specifications for the control of purchases by the Federal Government.

We have seen, therefore, the development of the standards idea coincident with the growth of industry. In the beginning each manufacturer in a small way endeavors to establish his own standards, then follows group standardization, and later, industry standardization. But to make the program complete, two further steps are necessary, namely, national standardization and international standardization. Our mutual interests in many lines had long shown the former to be desirable, and the Great War emphasized the necessity for the latter. Many of the standards of the great engineering bodies were of truly national character, but there was no authoritative body set up to give them the sanction of "American Standards," which they deserved, and there was no established procedure whereby desirable new standardization work could be undertaken where several interests were involved. A beginning has been made in international standardization through the coöperation of the various national standards laboratories and the functioning of such groups as the International Electrochemical Commission and a number of others. Some foreign countries had gone far in their organization for national standardization, and many of these national groups were so organized as to be in a position to take part in an international effort.

Work of the A.E.S.C. in National and International Standardization

These and other considerations, some of them having to do with the necessity of establishing an American position in connection with international standardization work, led to the organization of the American Engineering Standards Committee in 1918. This is not a standards-making body but a standards-approving body. Originally formed by the four national engineering societies and the American Society for Testing Materials, it has been expanded until at the present time it includes thirty-five national organizations in its member bodies, with fifty-eight official representatives forming what is known as the Main Committee. Its work includes more than 150 projects having official status or on which work is under way, and more than 350 trade, technical, or governmental bodies are coöperating through the more than 1350 individuals appointed to special or sectional committees. Its financial support comes from the payment by the member bodies of a certain fixed sum per member on the main committee, and from sustaining memberships subscribed by individual industries and by industry organizations. Projects in hand cover a very great variety of subjects, including many specifications for materials, methods of manufacture, safety codes for a wide variety of applications, dimensional standards, such as screw threads, keys for shafting, bolt, nut, and rivet proportions, pins and washers, the terminal markings of electrical apparatus, rating of electrical machinery, and many others. These projects involve the civil engineering and building trades, mechanical engineering, electrical engineering, automotive (automobile and aircraft), transportation, shipbuilding, ferrous and non-ferrous metallurgy, the chemical, textile, mining, and woodworking industries, the pulp and paper industry, and many miscellaneous subjects.

In addition to its work on national standardization, the Committee has coöperative relations with 18 other countries which maintain national standardizing bodies. Systematic coöperation with these other countries is carried out by correspondence and by conferences of the secretaries of the various national standardizing bodies. This coöperation is of great importance to the national work of the Committee, providing, as it does, means of closely following the trend of the standardization movement in the industrial countries of the world. There is every reason to believe that this international coöperation and coördination of standards will be of increasing value as our national work proceeds. In fact, quite a number of international conferences are in the process of organization at the present time for the consideration of standards, questions of vital importance to the various nations: as, for example, the international standardization of screw threads, an attempt to reach international accord on nut and bolt dimensions with the consequent standardization of wrench openings, work on international standardization of ball-bearing dimensions, the work of the International Electrochemical Commission in the field of electrical engineering, and many others, some of which are carried on through the agency of the A.E.S.C., and some through the agency of other international groups.

An exact evaluation of the benefits which have already accrued to American industry through the standards programs which have been carried on in its various branches is impossible, but it can be confidently stated that without these programs the industries could not have satisfactorily advanced. Neither can the value of future work along this line be predicted accurately in dollars and cents. It must be evident, however, that an ever-increasing program of simplification and standardization must be carried on to equalize our ever-increasing tendency to complexity of methods, products, and devices, and to stem the ever-rising tide of cost of living and to provide more recognized products which can be purchased with confidence that they will conform to known qualities and performances. We are very sure that the cost of engineering standardization is but a very small item compared to the benefits which through its application accrue to our people as a whole.

Scope of and Necessary Limitations to Standardization

The amount of standardization already done is relatively very little compared to that which remains to be done and still retain to us every necessary means of providing variety where variety is desirable. In these days of mass production, that engineer is most successful who can best adapt his new designs to the needs of the world and at the same time use a maximum of standard parts, standard materials, and standard methods, and which permit manufacture by the standard tools with which his factory is equipped. By using standards he is relieved of the necessity for carrying on much detailed labor in the establishment of features which come to him tried and proved and which leave him free to give more time and attention to the essential performance of the device which he is endeavoring to create. Imagine, for example, the amount of labor which would be involved if, in the design of an electric motor, the designer would be required to establish the sizes and number of threads of the screws used, the dimensions of the wire and the type and method of applying the insulation, the development of the quality and characteristics of the sheet steel, together with the desirable gages and methods of punching, insulating, etc. If he were further required to establish all basic calculations, systems of measurement, type and characteristics of bearings, size and construction of brushes and brush holders, and the thousand and one other details which go to make up a machine, years would be required for turning out a single design. This illustration can be carried into any engineering field, and the absolute necessity for standards becomes at once apparent. On the other hand, standards must not be carried to a point where they hamper the development of new devices, new types, and new applications. On account of the very great difficulties involved and which have been briefly outlined, there is little or no danger that our standards program will ever reach the point where industry will be so hampered. Manufacturing companies might well afford to give prizes to those of their engineers who succeed in producing the maximum of new and desirable results by the use of standardized processes, materials, and parts, and provide a bonus for those salesmen who sell a maximum of standards.

In his story The Bridge Builder, Kipling represents his hero as being responsible for every minute detail in the design and erection of his structure. The use of standard proved parts, methods, and constructions would have still left him with much responsibility, but would have greatly lessened his worry and saved his principals much money.

The fundamental source of difficulty in the welding of thin sheets, not suitable for the simple pressure welding used in connecting electrical wires and cables of aluminum, is the rapidity with which the metal oxidizes and the toughness and tenacity of the oxide film which is formed. The most effective way of removing the oxide in an aluminum weld is by the use of a flux. For aircraft work a flux is used consisting of potassium chloride 45 parts, sodium chloride 30 parts, lithium chloride 15 parts, potassium fluoride 7 parts, and potassium bisulphate 3 parts. This is a good flux for all general purposes, but many different mixtures are on the market which have their adherents. All aluminum fluxes are hygroscopic and have to be kept in airtight containers. Edgar T. Painton before the British Acetylene and Welding Association, Feb. 4, 1926.

Flue-Gas Computations

Abbreviated Methods for Checking Flue-Gas Analyses and Computing the Results—Heat Balance Without Ultimate Analysis of the Fuel

By ANDREW A. BATO,[1] NEWARK, N. J.

ANALYSES of boiler-furnace flue gases and of the exhaust gases from internal-combustion engines are not made as generally as they should be, although important and otherwise inaccessible facts can be determined by them. Even when flue gases are analyzed the results usually are not as accurate as those obtained by other methods of investigation in other fields. Many inaccuracies result from not checking the readings for possible self-contradictions. Furthermore, not all facts worth knowing are derived in as short and direct a manner as possible, thereby not yielding the complete benefit of the analysis.

In gases generated by the combustion of a fuel containing carbon, sulphur, hydrogen, and oxygen in known proportions, not every combination of CO_2, CO, and O_2 can be present, and with given quantities of CO_2 and CO, even if the latter is zero, only certain quantities of O_2 are possible and therefore correct. A method of checking the results of a flue-gas analysis from this point of view is the first object of this paper.

Furthermore, as a rule, the possibility is neglected of calculating in percentages the losses caused by heat carried away in the gases when only the analysis and the gas temperature, and not the analysis of the fuel, are known. Generally, these losses are calculated in heat units, and the percentage is obtained by dividing their sum by the heating value of the fuel. On considering that the numerator of this fraction contains the amount of gases generated, and the denominator the heat value of the fuel, and that both the amount of gases and the heat value of the fuel are in direct proportion to the amount of combustible constituents in the fuel, a method offers itself of forming the fraction directly, without calculating numerator and denominator first, by dividing both by the amount of combustible constituents, thus eliminating the latter. This method saves the labor of making a fuel analysis for calculating the losses in the gases; and even a heat balance can be made up with a proximate analysis, omitting the lengthy preparation of an ultimate analysis. The development of this and similar methods in numerical and graphical form is the second object of this paper.

Fundamental Facts

Before developing these methods, a summary of the essential laws of chemistry related to them will be presented.

The proper operation of any device burning fuel can be judged principally by the analysis of the flue gases and determining (1) whether the amount of excess air for combustion is greater than necessary, (2) and whether combustible gases are escaping unburned.

Before making use of the readings of the Orsat to answer these questions, it is advisable to check the figures obtained by the analysis, because errors can result due to some defect in the apparatus, some mistake in its operation, or the imperfect absorption qualities of the liquids in the pipettes.

If pure carbon is burned, the chemical process is characterized by the well-known symbols:

$$C + O_2 = CO_2$$

Considering the molecular weights of carbon and oxygen, respectively, this equation indicates that 12 lb. of carbon unite with 32 lb. of oxygen. However, as the Orsat and similar apparatus used for analyzing and measuring quantities of gases are based on volumetric measurement, the equation must be analyzed on the basis of volume. Looking at it from this point of view, the left side of the equation represents the combination of one molecule of carbon with one molecule of oxygen. On the right-hand side one molecule of carbon dioxide is represented. The number of gas molecules being the same on both sides, the volume of the gases before and after the chemical process of combustion remains the same. The meaning of this for the various cases of combustion is, that—

1 If carbon is burned in the amount of oxygen not more nor less than required for perfect combustion, the resulting amount of the carbon dioxide will be one cubic foot for each cubic foot of oxygen used, the gas changing its weight and not its volume.

2 If carbon is burned in oxygen exceeding the required amount for perfect combustion, the case will be the same: a mixture of gases will be obtained consisting of oxygen and carbon dioxide, but the volume of this mixture will be equal to the volume of oxygen used.

3 If carbon is burned in air, which is a mixture by volume of 21 per cent of oxygen and 79 per cent of nitrogen, containing not more nor less oxygen than is required for perfect combustion, the result will be a mixture of gases, containing 21 per cent of carbon dioxide and 79 per cent of nitrogen, provided that a perfect combustion resulting in CO_2 takes place, without generating CO.

4 If carbon is burned to CO_2 in air containing a quantity of oxygen exceeding the amount required for perfect combustion, the resulting mixture of gases will contain oxygen and carbon dioxide whose sum is 21 per cent of the mixture by volume, the remaining 79 per cent being nitrogen.

The principle involved in case 4 provides a method for checking the gas analysis. Hydroxide of potash, the reagent generally used for absorbing carbonic acid, is easily obtained and can be used many times before it is exhausted, therefore the quantity of carbon dioxide measured will most likely be correct. The pyrogallic acid used for the determination of oxygen is not always pure, mistakes can occur in preparing it, a slight carelessness in handling may weaken it, it does not react promptly even in its best condition, and it is quickly exhausted. Therefore, while the amount of carbon dioxide indicated by the analysis may be correct, it may be necessary to increase the reading for oxygen by an amount sufficient to obtain 21 as the sum of the percentages for carbon dioxide and oxygen.

Under practical conditions, however, it may happen that the combustion is more or less imperfect, resulting in the production of a small amount of carbon monoxide. The formation of carbon monoxide is symbolized by the equation

$$2C + O_2 = 2CO$$

The equation shows that the volume of carbon monoxide is twice that of the oxygen used. If air is used for generating carbon monoxide, as for instance in a gas-producer operated with charcoal, and if the gas contains no carbon dioxide and no oxygen, then for every 100 cu. ft. of air used 121 cu. ft. of gas will result because the 21 cu. ft. of oxygen was doubled in volume when it was changed into carbon monoxide. The gas obtained will consist of 79 cu. ft. of nitrogen and 42 cu. ft. of carbon monoxide; 65.3 per cent of it will be nitrogen and 34.7 per cent carbon monoxide.

For the general case, if a fuel is burned containing carbon only as a combustible constituent, like charcoal or coke, the products of combustion will contain both CO and CO_2 and the correctness of a flue-gas analysis can be checked by the following formulas:

$$CO_2 + CO + O_2 + N_2 = 100$$

and

$$\left[CO_2 + \frac{1}{2}CO + O_2\right] : N_2 = 21 : 79$$

The first equation states that the sum of percentages of all constituents of a mixture must equal 100. The second equation states

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that the volume of the original oxygen expressed in terms of the resulting CO_2, CO and O_2 is to the volume of the nitrogen as 21 is to 79. One-half of the percentage of CO is used because the original oxygen volume is doubled when the gas is formed, as stated above.

The cases enumerated above represent but a few of those met with in practice, as mineral coal, oil or its derivatives, and gas fuels contain combustible hydrogen in addition to carbon. Of the fuels generally used, anthracite contains the least amount of hydrogen. The bituminous coals contain greater percentages of hydrogen and still more is found in crude oil, the quantity in the distillates increasing with a lower boiling point. Of the gases, marsh gas, or methane, has the highest percentage of hydrogen, twenty-five per cent of it in weight being hydrogen, whereas anthracite contains less than one per cent.

The combustion of hydrogen takes place according to the formula

$$2H_2 + O_2 = 2H_2O$$

which means, that two parts by volume of hydrogen unite with one part by volume of oxygen, or, considering the atomic weights, that two parts by weight of hydrogen unite with sixteen parts by weight of oxygen. If the combustion takes place in an enclosed space containing nothing but the two gases in proper proportion at a normal pressure, the condensation at normal temperature of the steam generated will result in water and a small quantity of vapor, a high vacuum being formed in the combustion chamber. If the inside of a floating bell is used for a combustion chamber for burning hydrogen with pure oxygen, the bell being balanced with a counterweight in a manner to maintain a constant pressure, the original volume will practically disappear as the steam condenses to water after normal temperature is reached.

If hydrogen is burned in an amount of air not more nor less than necessary for perfect combustion, the result will be a gas consisting of pure nitrogen, and some condensed water on the walls of the combustion chamber.

In practice, the flue gases from which the samples are taken have a temperature higher than the boiling point of water; and for this reason the water generated by the combustion of hydrogen is suspended in them in the form of vapor. When taken into the Orsat apparatus, however, this vapor condenses because of the cooling effect of the water jacket around the measuring burette.

MAXIMUM CO_2 CONTENT OF FLUE GASES

When burning a fuel containing carbon and hydrogen as combustible constituents, and no other gas, combustible or incombustible, provided the exact amount of pure oxygen necessary to give perfect combustion to CO_2 and H_2O is used and provided no CO is generated, three times as much oxygen will be used to burn a pound of hydrogen as will be used to burn a pound of carbon; because to burn 12 lb. of carbon, 32 lb. of oxygen are required, corresponding to a ratio of 3 : 8, whereas, for every pound of hydrogen, 8 lb. of oxygen will be needed, the ratio being 1:8. If, therefore, the ratio of the amounts of carbon and hydrogen contained in the fuel are known, it will be possible to determine what part of the oxygen used will change into CO_2, and what part of it will become water and practically disappear from the volumetric analysis. If a fuel contains h per cent of hydrogen and c per cent of carbon by weight, and requires 100 cu. ft. of oxygen for complete combustion, the quantity of O_2 changed into CO_2 will be in a ratio to the amount of O_2 converted into H_2O, as c is to $3h$. The number of cubic feet of carbon dioxide obtained will be

$$\text{Cubic feet of } CO_2 = \frac{100}{c + 3h} \times c = \frac{100}{1 + 3h/c}$$

If air is used instead of pure oxygen, the 21 cu. ft. of oxygen contained in 100 cu. ft. of air will change into carbon dioxide and water in the same ratio, and the number of cubic feet of CO_2 will be

$$\text{Cubic feet of } CO_2 = \frac{21}{1 + 3h/c}$$

The total amount of dry products of combustion is obtained by adding to the last expression 79 cu. ft. of nitrogen for every 21 cu. ft. of oxygen used.

Owing to the fact that the apparatus for chemical analysis is designed for volume measurement on a percentage basis rather than by cubic feet, the formula must be changed accordingly to read—

$$\text{Per cent of } CO_2 = \frac{\dfrac{21}{1 + 3h/c}}{\dfrac{21}{1 + 3h/c} + 79} \times 100 = \frac{8.86}{0.422 + h/c}$$

The numerical constants of this formula may differ slightly in the last decimal place, according to the numerical values used for the composition of air, which does not contain oxygen and nitrogen in the proportion of 21 to 79; and the atomic weights, especially that of hydrogen, differ according to various authorities.

The percentage of CO_2 thus obtained is the maximum for the fuel in question, for in every other case, either with more or less air

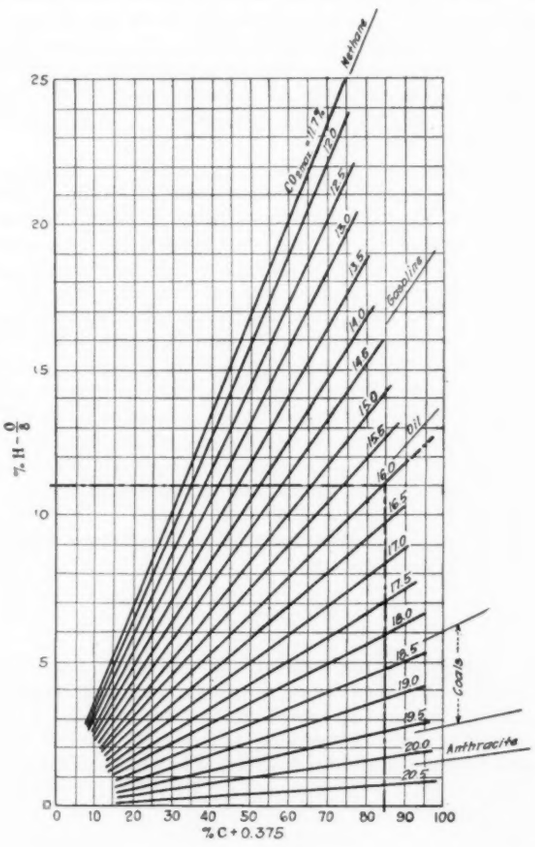


FIG. 1

and when some of the carbon is changed into carbon monoxide, the percentage of CO_2 will be lower. The formula shows that the maximum of CO_2 obtainable, $CO_{2(max.)}$, depends in the case described only on the ratio of hydrogen to carbon contained in the fuel, and is characteristic for this ratio.

The formula is subject to slight changes if used in connection with the combustion of natural fuels containing oxygen and sulphur, as nearly all coals do. The oxygen contained in the fuels will bind some of the hydrogen, and it is to be remarked that there will always be an excess of hydrogen for combustion with the oxygen of the air, whereas the whole of sulphur will be available for being burned with the oxygen of the air. The formula completed for use in connection with natural fuels as described will be—

$$\text{Per cent of } CO_2 = \frac{8.86}{0.422 + \dfrac{h - o/8}{c + 0.37\,s}}$$

o and s being symbols for the percentages by volume of oxygen and sulphur in the fuel.

It will be shown later, that a knowledge of the amount of

$CO_{2(max.)}$ for a given fuel is of the greatest importance. For this reason Fig. 1 has been prepared, from which the amount of $CO_{2(max.)}$ can be determined if the percentages of C, H, O, and S in the fuel are known.

Example. The ultimate analysis of a heavy fuel oil gives for C + 0.37 S the value 85 per cent and for H — $O/8$, 11 per cent. For this fuel $CO_{2(max.)}$ will be 16.0 per cent. (See dash-dotted lines in Fig. 1.)

It has been shown that if carbon is burned in an excessive amount of air the sum of CO_2 and O in the flue gases will always be constant, namely, 21 per cent. This, however, will not be the case when a fuel is burned containing hydrogen and carbon. When there is no excess air and the combustion is perfect, the CO_2 content will be equal to $CO_{2(max.)}$. If to a flue gas having $CO_2 = CO_{2(max.)}$ air is added from any source whatsoever (through grate, burner, or cracks in the brickwork of the boiler), the sum $CO_2 + O_2$ will be greater than $CO_{2(max.)}$, but less than 21. This sum, however, will approach 21 as more and more air is added to the gas, 21 corresponding to an infinite amount of air mixed with the products of perfect combustion. However, there will always be a definite relation between the contents of CO_2 and O_2 of the flue gases on one side, and the $CO_{2(max.)}$ of the fuel burned on the other. This can be deduced mathematically as follows:

The total amount of a sample of, say, 100 cc. of flue gas can be divided into two parts. The first part will be the sum of the total amount of CO_2, the nitrogen released when it was formed, and the nitrogen released when the H_2O was formed by the combustion of hydrogen. The second part will be simply air, containing nitrogen and oxygen in the ordinary ratio of 79 to 21. What is needed is a formula for the $CO_{2(max.)}$ of the fuel in question, expressed as a function of the percentages of CO_2 and O found in the flue gas. Let the sample of 100 cc. of flue gas contain k per cent of carbonic acid, n per cent of nitrogen, and o_2 per cent of oxygen. For the combustion a certain amount of oxygen o_1 was used, to which belonged a certain amount of nitrogen n_1, which after combustion became a part of the total n per cent of nitrogen of the flue gas. The n_1 can be obtained by subtracting the amount of nitrogen corresponding to the oxygen o_2 which took no part in the combustion (and was therefore actually measured in the flue-gas analysis) of the total n. Thus n_1 will be:

$$n_1 = n - \frac{79}{21} o_2 \quad \ldots\ldots [1]$$

Of the sum $n_1 + k$, representing a sample of gas which is a part of the 100 cc. mentioned above, k will represent a percentage equal to the $CO_{2(max.)}$ of the fuel burned, as this sum contains no oxygen, which would be a sign of excess air, and no CO. To find what percentage k is of the sum $n_1 + k$, divide k by this sum and multiply it by 100, thus

$$CO_{2(max.)} = \frac{100k}{n_1 + k} \quad \ldots\ldots [2]$$

Now if

$$n + k + o_2 = 100 \quad \ldots\ldots [3]$$

there are three equations which, combined, give for $CO_{2(max.)}$ the simple formula

$$CO_{2(max.)} = \frac{21k}{21 - o_2} \quad \ldots\ldots [4]$$

If the products of combustion of any fuel are analyzed and the percentages CO_2 and O_2 are determined, it is possible to find $CO_{2(max.)}$ of this fuel with the aid of Equation [4] without requiring a chemical fuel analysis. It is necessary, however, that the combustion be complete and that no unburnt gases escape into the flue. This condition can be secured by burning the fuel during the period of taking one sample of gas with such an excessive amount of air that there will be no possibility for combustible gases to escape unburned. When burning coal, a content of 5 to 6 per cent of CO_2 in the flue gas will provide a sufficient security for fulfilling this condition even in poorly designed furnaces.

For facility in using Equation [4], Fig. 2 has been devised. The sum of CO_2 and O_2 is one of the coördinates instead of O_2, as the Orsat apparatus indicates this sum directly, whereas O_2 alone can be obtained only through subtraction.

Example. The products of combustion from a fuel-oil burner set to give smokeless combustion with much excess air contain 8 per cent CO_2 and 18.5 per cent $CO_2 + O_2$. The value of $CO_{2(max.)}$ will be found from Fig. 2 to be 16 per cent.

Checking the Analysis of Flue Gas

In case of complete combustion Fig. 2 can be used to check the correctness of the analysis. This is done by finding the coördinates corresponding to the values obtained for CO_2 and $CO_2 + O_2$. Their intersection must be on the corresponding $CO_{2(max.)}$ line as found above.

Example. In the case above the amount of excess air has been reduced so that the analysis gives 12 per cent CO_2. The sum $CO_2 + O_2$ must be 17.2 per cent; if not, there is either an error in the analysis or the combustion is not complete.

Assuming, now, the combustion to be incomplete but the hydrogen contained in the fuel to have been burned perfectly and the flue gases to contain CO only as an unburned combustible gas, a connection can be found between the percentages of O_2, CO, CO_2, and the $CO_{2(max.)}$, as in the case of perfect combustion. Keeping the symbols as used above and using k_m for the percentage of carbon monoxide, the formula becomes—

$$CO_{2(max.)} = \frac{21\,(k + k_m)}{21 - o_2 + 0.395k_m} \quad \ldots\ldots [4a]$$

It can be readily seen that for the case of a complete combustion, that is, if k_m is made equal to zero, Formula [4] will result.

While Formula [4] for $CO_{2(max.)}$ may be used to determine the maximum amount of carbon dioxide obtainable by burning a certain fuel and regulating the fire so as to have an excessive amount of air in the combustion chamber and then analyzing the flue gases, Formula [4*a*] may be used to determine the amount of CO in the gases, or to check the correctness of the analysis, especially as the absorbent for CO (a solution of cuprous chloride in hydrochloric acid or ammonia) cannot be relied upon if it is not fresh.

To facilitate the use of Formula [4*a*] Fig. 3 has been drawn, with the percentages of CO_2 and $CO_2 + O$ as coördinates, and lines of equal CO marked on it. The diagram is drawn for a fuel with $CO_{2(max.)}$ equal to 16.0 per cent, corresponding to a heavy oil, but can be made up for any fuel. The method is as follows:

Find the point corresponding to CO_2 equal to $CO_{2(max.)}$ and $CO_2 + O$ equal to $CO_{2(max.)}$ (in Fig. 3 both have the value 16.0 per cent) for which case $O_2 = 0$. Connect this point, which represents perfect combustion, with the point CO_2 equal to 0 and $CO_2 + O_2$ equal to 21, that is, with the point for which the gases are mixed with an infinite amount of air, so that the percentage of carbon dioxide is zero as compared with the percentage of oxygen. For this point CO also equals zero, otherwise the gases could not contain 21 per cent of O_2. The line obtained will be the locus of all points for complete combustion. This can be seen if in Equation [4*a*] the value of k_m is set equal to zero, in which case the equation of the above line is obtained. To draw the lines connecting all points having the value of 1, 2, 3, etc., for CO, replace these values for k_m in Equation [4a] and make $k = 0$. The values of o_2 thus obtained will be the starting points for the lines CO equal to 1, etc., which are to be drawn parallel with the line of complete combustion.

The diagram is to be used for checking the correctness of flue-gas analysis as shown in the following example.

Example. The fuel oil of the previous example for which $CO_{2(max.)}$ equals 16.0 per cent may burn to 12 per cent CO_2 and 15.8 per cent $CO_2 + O_2$. In this case unless the gases contain 1.5 per cent CO, there is an error in the analysis.

In the case of complete combustion Fig. 3 may be used for checking in the same way as Fig. 2, as the oblique lines in the latter indicating various values of $CO_{2(max.)}$ are the same as the lines of complete combustion in Fig. 3, in a system of the same coördinates.

The error most frequently encountered in actual practice is a too low reading for the percentage of oxygen in the gases. This results in a too low value for the chimney losses through sensible heat in the heat balance, and consequently in a too high value for the unaccounted-for losses. In an example taken from the literature, a

coal of $CO_{2(max.)}$ equal to 18.5 per cent was burned on a chain grate with CO_2 equal to 10.4 per cent, O_2 equal to 8.0 per cent, and CO equal to 0, and with 59 per cent excess air. If the temperature of the air used for combustion was 60 deg. fahr. and that of the flue gases leaving the boiler 420 deg. fahr. the chimney losses amounted to 13.6 per cent according to these figures. The correct value for O_2, however, is 9.2 per cent, and the excess air amounts to 76 per cent and the chimney loss to 14.7 per cent, or 1.1 per cent more than the value based upon the unchecked analysis.

Similar diagrams have been drawn by Bunte, Ostwald, Dr. Herberg,[2] and others. Methods by which losses can be calculated have been added by the author as described below.

On the diagram of Fig. 2 a row of lines shows the amount of excess air E mixed with the flue gases generated by perfect combustion, the quantity of which is given as a multiple of the air necessary for perfect combustion. Thus the line E equals 0.6 connects all points which represent combustion with an amount of air exceeding the amount necessary for perfect combustion by 60 per cent. For the example plotted in the diagram, E equals 0.3. The line E equals 0.0 connects points with no excess air.

A formula for E is given using symbols similar to those in the Equations [1] to [3]:

$$E = \frac{o_2 + n_2}{o_1 + n_1} = \frac{o_2 + 79/21}{21/79\, n_1 + n_1} o_2$$

Eliminating o_2 and n_1 with the aid of Equations [2] and [4],

$$E = \frac{(CO_{2(max.)} - k)79}{k(100 - CO_{2(max.)})} \quad \ldots\ldots\ldots\ldots\ldots\ldots [5]$$

which is a handy formula for drawing lines of equal E.

To prove that in a system of coördinates CO_2 and $CO_2 + O_2$ these lines will be straight, replace the value of $CO_{2(max.)}$ in [5] taken from [4] and substitute $CO_2 + O_2$ for O_2. Then—

$$O_2 = (CO_2 + O_2) - CO_2$$

The equation thus obtained will be one of the first degree representing a row of straight lines for E.

The latter lines give a general view of the significance of the CO_2 content when judging the results obtained in burning various fuels. Thus 15.3 per cent CO_2 in the flue gas produced through the combustion of anthracite having a $CO_{2(max.)}$ equal to 20.0 per cent means 30 per cent excess air, the same percentage of CO_2 in the gases of a high-volatile coal with $CO_{2(max.)}$ equal to 18.5 per cent means only 20 per cent excess air.

Just as $CO_{2(max.)}$ is determined for a fuel, $CO_{(max.)}$ can likewise be calculated, this being the highest value of the percentage of carbon monoxide in a case where all the carbon of the fuel is turned into CO with no oxygen left in the products of combustion. Thus $CO_{(max.)}$ can be obtained by substituting zero for k and o_2 in [4a].

The value of $CO_{(max.)}$, if once known, can, in combination with $CO_{2(max.)}$, be used to calculate the values of E in cases where CO figures in the products of combustion, in the same manner as it has been calculated for complete combustion. It can also be proved that the lines connecting points of equal E are straight.

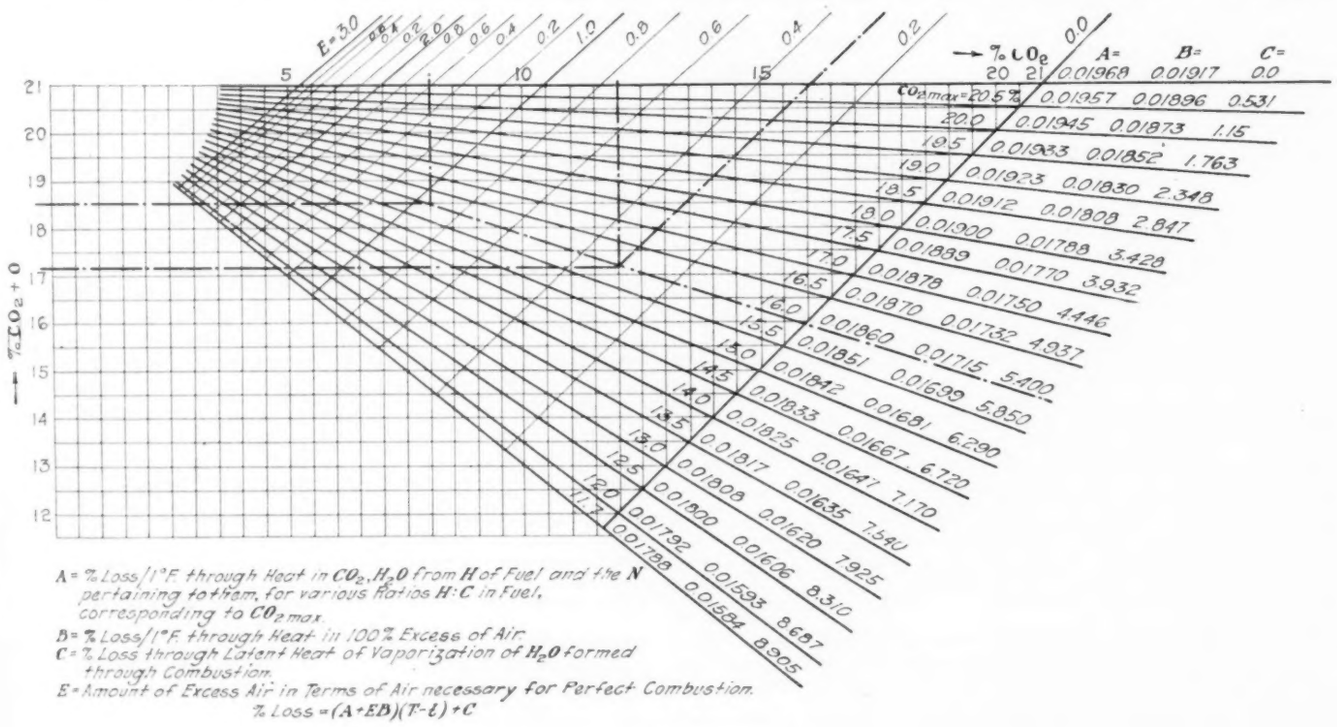


FIG. 2

Following this method the lines in Fig. 3 have been calculated (the example marked in the diagram having E equals 0.18, estimated), and in addition a number of lines for the cases in which the total air is less than the amount necessary for the perfect combustion. These lines are indicated as lines of equal values of e.

It can readily be seen that CO is generated in a great majority of cases when air is present in an excessive amount, proving that an imperfect and incomplete combustion is due rather to poor mixing of the gases and cooling below the point of ignition before ending combustion, than to lack of air.

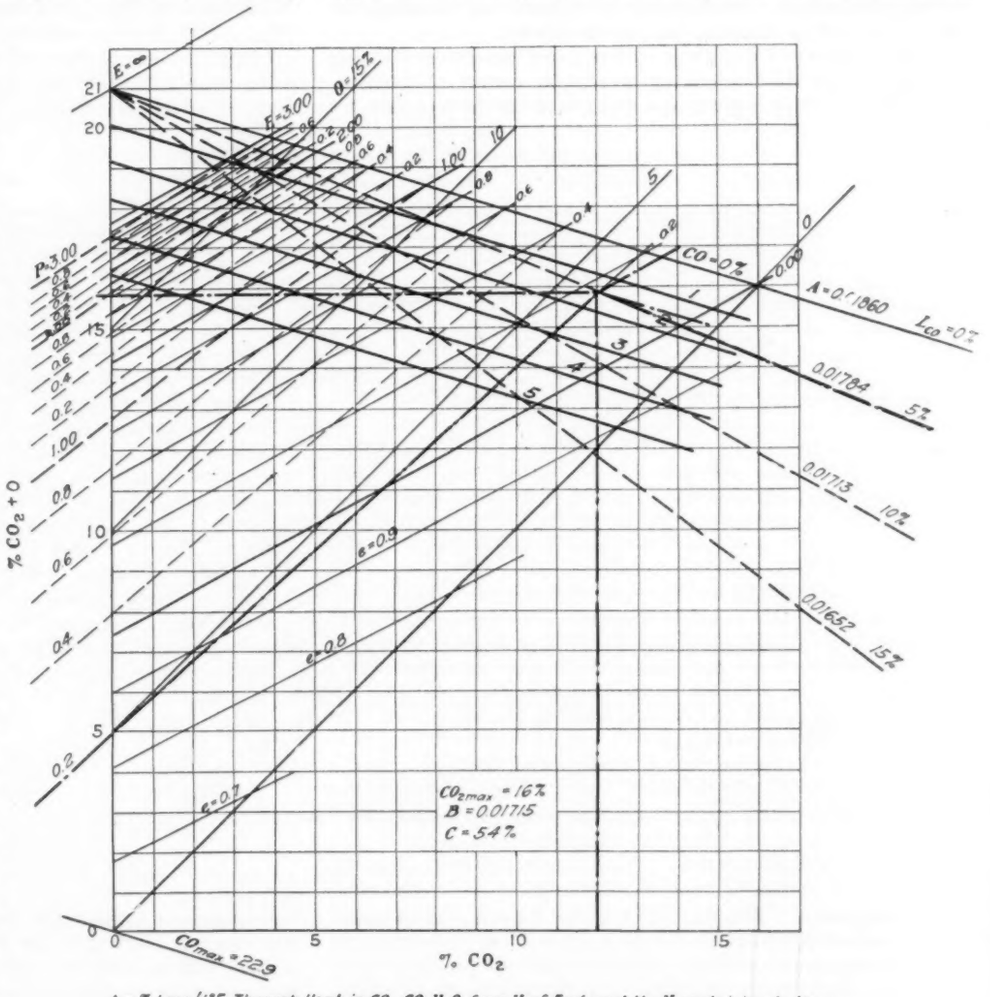
In actual practice it will be extremely rare to find a gas analysis corresponding to a point in the region of the e lines; it may be found in an oil furnace with a highly reducing flame where the amount of air is kept purposely very low, or momentarily in the exhaust gases of a crude-oil engine when the air is throttled out of proportion through irregular working of the governor.

In the case of incomplete combustion it is not the carbon monoxide only that may escape unburned, but also some hydrogen and hydrocarbons. To demonstrate the influence of this possibility on the composition of the flue gases, the theoretical case will first be investigated in which all the carbon of the fuel is burned to CO_2 and all the hydrogen will escape unburned, without any air present in the products of combustion. This will result in a flue-gas analysis giving a higher content of CO_2 than $CO_{2(max.)}$. For the oil mentioned, having $CO_{2(max.)}$ equal to 16.0 per cent, the CO_2 will be as high as 18.03 per cent, called "CO_2 ultramaximum," having a symbol CO_{2um}. The definition of $CO_{2(max.)}$ as given

[2] Dr. G. Herberg: Feuerungstechnik und Dampfkesselbetrieb.

above still remains justified, as a combustion in which all the hydrogen escapes unburned, resulting in the production of CO_{2um}, with or without excess air, will never occur. That CO_{2um} must be greater than $CO_{2(max.)}$ can be readily seen, when it is considered, how the hydrogen of the gas containing CO_{2um} would be burned perfectly to obtain a gas with $CO_{2(max.)}$. To this end enough air should be mixed with the gas for the combustion of the hydrogen. After combustion, as a consequence of condensation, the presence of H_2 and O_2 could not be determined by volumetric analysis. On the other hand the nitrogen will remain, increasing the volume of gas by 0.88 per cent for each per cent of hydrogen burned. Thus the total volume of the gas is greater if containing hydrogen than if this hydrogen burned and condensed is replaced by the corresponding amount of nitrogen in the gas. When the total volume of gas increases, the percentage of CO_2 decreases until it reaches $CO_{2(max.)}$ or, if air is mixed with the gases, a corresponding lower value. In a similar way, if instead of hydrogen some hydrocarbon with a sufficiently high content of hydrogen escapes unburned, a higher percentage of CO_2 will result; as in the case of the oil with $CO_{2(max.)}$ equal to 16.0 per cent, if all the hydrogen escapes as CH_4, the percentage of CO_2 will be 17.93.

Since the escaping of unburned CO results in a lower percentage of CO_2 and, on the other hand, unburned hydrogen or hydrocarbons cause a higher content of CO_2, there must be a case in which both kinds of gases escape unburned in such a proportion that the effect of their presence keeps the balance by giving the proper amount of $CO_{2(max.)}$ as a result, or, if air is mixed with the gases, Fig. 3 will give a value of CO equal to 0.0 for the amount of CO_2 and $CO_2 + O_2$ found by the analysis, although not only unburned CO is present, but hydrocarbons as well. For example, if all the hydrogen of the heavy oil mentioned above should be present in the form of CH_4, a combination is theoretically possible with 3.05 per cent CH_4 and 1.58 per cent CO giving 16.00 per cent of CO_2, which is the proper amount. Likewise when burning a soft coal with $CO_{2(max.)}$ equal to 18.5 per cent with all the hydrogen in the flue gases in the form of hydrogen, the result would be 19.5 per cent CO_2; and with the hydrogen in form of C_2H_4 (this being, according to the results of many observations, the average composition of a series of hydrocarbons present in the gases in case of imperfect and incomplete combustion), a combination is theoretically possible with 1.43 per cent CO and 1.32 per cent C_2H_4, resulting in the proper amount of 18.5 per cent for CO_2. From the theoretical standpoint this would make the use of Fig. 3 impossible for purposes of checking whether or not CO is present, but experience[3] shows that such conditions do not exist to any appreciable degree in stoker-fired furnaces with a uniform state of combustion, the amount of escaping hydrogen and hydrocarbons representing only a negligible fraction of the carbon monoxide as long as the latter does not exceed the usual low limit, and even then this amount does not rise above 30 per cent of the CO. On the other hand, during moments of irregular fuel supply, the most surprising analysis is often obtained. For instance, in the case of an overfeed stoker, if a great amount of green fuel is suddenly pushed over the incandescent fuel bed, or an avalanche takes place, the result obtained from the diagram for CO may even be negative. The reason for it is the fact that when coking some kinds of coal the first products of distillation contain a high percentage of CO_2, which mixes with the flue gas without a corresponding amount of nitrogen, as it is not a product of combustion with air, and results in too high values for $CO_2 + O_2$ and CO_2 for the diagram Fig. 3 and correspondingly low ones for CO. On the other hand, if the fire is banked for a long time, the fuel on the grate will contain less hydrogen in proportion to the carbon than the green fuel, as most of this gas was distilled with the volatile part of the fuel. As a result of long experience it may be stated, however, that seven to eight out of ten analyses show a perfect accordance with the diagram, and only two to three a discrepancy equal to 0.1 to 0.3 per cent.



A = % Loss/1°F. Through Heat in CO_2, CO, H_2O from H of Fuel and the N pertaining to them.
P = Amount of Present Air in Terms of Air necessary for Perfect Combustion
B = % Loss/1°F. Through Heat in Air Present, if P=1.
C = % Loss Through Latent Heat of Vaporization of H_2O formed from H of Fuel.
L_{CO} = % Loss Through CO.

$$\% \text{ Loss} = (A + PB)(T - t) + C + L_{CO}$$

FIG. 3

After the flue-gas analysis has been checked with the aid of the diagrams, it may be used, together with the readings of thermometers used for measuring the temperature of the flue gas, T, and that of the air used for combustion, t, to calculate the percentage of the heating value of fuel lost in the sensible heat of the departing gases, without knowing the heating value of the fuel, and to

CALCULATING THE LOSSES

[3] See also tests published in Bulletin 135 of the U. S. Bureau of Mines: Combustion of Coal and Design of Furnaces, by Henry Kreisinger, C. E. Augustine, and F. K. Ovitz.

make a heat balance without an ultimate analysis of the fuel. The train of ideas leading to this method is as follows:

If one pound of carbon is burned in air but with no excess air, and the combustion is perfect, 11.52 lb. of air are used, producing 3.67 lb. of CO_2 and 8.85 lb. of N_2, and giving, when multiplied with the corresponding values of their specific heats, a total heat capacity of 2.864 B.t.u. per deg. fahr. This heat capacity multiplied by the difference $T - t$ will give the loss of heat in B.t.u. due to the heating of the gases from the temperature t to T and carried away through the flue, and if divided by the heat generated through burning the one pound of carbon, 14,540 B.t.u., will give the loss as a fraction of the heat value of the fuel, or multiplied by 100, the percentage loss as used in the heat balance of a boiler furnace or any fuel-consuming appliance. If instead of one pound of carbon one pound of fuel is burned containing carbon alone as a combustible constituent and incombustible ashes besides, the percentage of loss in the heat carried away in the gases will remain the same as when pure carbon was burned, provided the difference of temperature $(T - t)$ also remains the same and the combustion is perfect, because, corresponding to the decrease of the heat value of the fuel as a consequence of mixing ash with the carbon, there will be a proportionate decrease of the amount of gases produced, with a corresponding lower heat capacity and consequently less heat carried away in the gases. In other words, the amount of gases generated, their heat capacity, and the heat carried away in them is in direct proportion to the amount of *carbon* burned, and not to the amount of fuel burned. If a fuel is used consisting of 50 per cent carbon and 50 per cent ash, only one-half of the heat will be produced; on the other hand, only one-half as much gas will be generated, carrying away only half the amount of heat, as compared with the burning of pure carbon. As the percentage of loss is only a fraction, with the loss as the numerator and the heat value as the denominator, the value remains the same if both numerator and denominator are divided by two or any other number. Thus it may be said that the percentage of loss is independent of the heating value of the fuel. To prepare a short way of computation, the water value of the gases may be divided by the heating value of carbon, obtaining by this the heat capacity of the gases produced per generated heat unit. For calculations on a percentage basis, multiply by 100, getting for carbon $\frac{2.864 \times 100}{14{,}540} = 0.01968$ per cent. This number, multiplied by the difference $T - t$, gives the heat loss in per cent of the heating value of the fuel, and therefore represents the loss per 100 B.t.u. generated per deg. fahr. rise of temperature of the flue gases above the temperature of air used for combustion.

When burning pure hydrogen without an excess air, the combustion being perfect, and figuring with the higher heating value of this element, the heat loss per 100 B.t.u. generated per deg. fahr. will be 0.01662, calculated for the heat of the water vapor and nitrogen of the gases only, and not calculated for the latent heat of the water vapor, which will be considered later.

The formula generally used to determine the loss due to heat carried away in the water vapor produced and through the heat used to evaporate the water generated by burning hydrogen, is—

$$\text{Loss} = 9H[(212 - t) + 970.4 + 0.48\,(T - 212)]$$

212 deg. fahr. being the boiling point of water, 970.4 B.t.u. the latent heat of vaporization at that temperature, 0.48 the specific heat of water vapor under constant pressure, and H the weight of hydrogen burned.

Now there is nothing in the physical phenomena occurring during the combustion of hydrogen and the utilization of the heat produced that would make necessary the use of the latent heat of 970.4 B.t.u. at the temperature of 212 deg. fahr. as expressed in this formula. On the contrary, when burning hydrogen, or any fuel containing it, for instance methane, the fuel practically used in form of natural gas containing the highest percentage of hydrogen, water in the flue gases does not evaporate at all, being produced at a temperature much higher than the critical temperature of water, and it does not, as a rule, condense in a boiler or economizer either. The dewpoint of the gases produced, when the combustion is perfect, is at 141 deg. fahr. Fifteen and four-tenths per cent of the total amount of water produced still exists in form of vapor at a temperature of 80 deg. fahr., and 2.55 per cent of it at 32 deg. fahr. During the cooling of the gases, condensation takes place at constantly diminishing temperatures, the latent heat increasing correspondingly. If the combustion were to take place with some excess air, the dewpoint would be lower and the amounts of vapor contained in the gases at any temperature higher, as well as in the case of a fuel containing less hydrogen than does methane. The above formula can therefore be changed without any misrepresentation of the phenomena by placing the latent heat corresponding to the temperature t instead of 970.4 and simply adding $T - t$ multiplied with the specific heat of water vapor. The final result will naturally be the same.

For general practical use, therefore, and for the purpose of the following calculations the latent heat corresponding to 80 deg. fahr., an average boiler-room temperature and temperature of air used for combustion, may be used, having the value of very nearly 1047 B.t.u. and decreasing at a rate of 1 B.t.u. corresponding to a rise of 2 deg. fahr. for t, a negligible amount in the heat balance, the exactness of which, besides, is limited, according to established standards, to a discrepancy of ± 3 per cent.

The above formula, using the latent heat of 1047 B.t.u. and neglecting the difference that may occur between t and the corresponding 80 deg. fahr., will take the following simple form:

$$\text{Loss in B.t.u.} = 9H[1047 + 0.48\,(T - t)]$$

Using the part of the formula representing the heat necessary to raise the temperature of the water vapor from t to T in the form $9H \times 0.48\,(T - t)$ makes it possible to treat the losses caused by this "visible heat" together and uniformly with the losses due to heating of the dry chimney gases. The loss through the latent heat of vaporization, however, has to be calculated separately, and will be considered later.

Thus far it has been assumed that the temperature of the fuel and the moisture contained in it are the same as, or differ only to a negligible amount from, those of the air used for combustion. When fuel oil is used, however, it is preheated with steam to a temperature of from 150 to 190 deg. fahr., in which case the figure 1047 may be replaced by the corresponding value of the latent heat. The heat necessary to preheat the oil is to be subtracted from the loss as given in the above formula, the value of it being about 0.28 per cent.

Using the lower heating value of hydrogen, the loss per 100 B.t.u. and 1 deg. fahr. is practically the same as for carbon, namely, 0.01945, and remains, therefore, the same for mixtures of the two in any proportion, thus facilitating greatly the calculation. In this country, however, the use of the higher heating value being established, the loss per 100 B.t.u. and 1 deg. fahr. for various mixtures of carbon and hydrogen, without the loss due to the heat of vaporization, A, must be computed according to the proportion of carbon and hydrogen in the fuel. This proportion, however, determines the $CO_{2(max.)}$ of the fuel and is determined by it, for which reason the values for factor A could be marked on Fig. 2 on the lines for each value of $CO_{2(max.)}$, preferably numerically. This method makes them more readily usable than a representation by a curve. Interpolation, on the other hand, can be performed through numerical calculation.

The losses carried away in the gases through excess air can be computed in a similar way. The amount of air used to produce 1 B.t.u. in burning carbon is somewhat greater than the amount used in burning hydrogen. For this reason, if both elements are burned with the amount of air corresponding to double that necessary, or when the excess air equals the amount that was actually used for combustion ($E = 1.0$ according to our former notations), the loss for the same amount of heat generated (calculating it in per cent) will be somewhat less if the heat is generated by burning hydrogen than if it is generated by burning carbon, provided $T - t$ is the same in both cases.

For $E = 1.0$ the loss per 100 B.t.u. and 1 deg. fahr. will be 0.01926 when burning carbon, and 0.01348 when burning hydrogen. For various mixtures of the two this quantity, called B, is shown in Fig. 2 on the corresponding lines of $CO_{2(max.)}$.

The loss due to the heat of vaporization of the moisture formed in burning the hydrogen will naturally increase with the increase in percentage of hydrogen in relation to that of carbon, and will there-

by increase with the decrease of $CO_{2(max.)}$ as the latter is given through the quotient H/C. It can be expressed as a fraction or percentage of the heat value of the mixture or compound of carbon and hydrogen the same as the losses given above for heating the gases and the vapor, but it will be independent of $T - t$. These values are given in Fig. 2 as factor C.

With the aid of a flue-gas analysis, in the case of complete combustion, the losses due to heat carried away in the flue gases for dry fuel can be computed with the aid of the diagram Fig. 2, and the simple formula:

$$\text{Per cent of loss} = (A + EB)\,(T - t) + C$$

Example. In the case marked on Fig. 2, $CO_2 = 12$ per cent, $CO_2 + O_2 = 17.2$ per cent, $E = 0.3$ per cent, and the percentage of loss $= (0.01860 + 0.3 \times 0.01715)\,(T - t) + 5.4$.

For use in a heat balance this formula is subject to the following corrections.

In the case of coal it must be borne in mind that not all the fuel that comes to the grate will be burned; some of it falls through the grate and some is removed with the clinkers. The amount of fuel actually burned is therefore smaller, and the equation will give the loss in per cent of this decreased quantity of fuel. By reducing the percentage according to the ratio of the fuel actually burned to the total quantity given up to the grate, the combustible parts contained in the refuse must be taken into consideration as pure carbon, as the volatile matter containing the hydrogen was distilled out in the fire bed.

The losses, as calculated above, can be used equally well in the heat balance made up on the dry as well as on the wet basis. They contain the losses through heat carried away in the dry gases plus those through heat used for evaporating and superheating the water vapor generated through combustion of hydrogen. They do not contain, however, the losses caused by the moisture in the fuel and in the air which may be calculated in any well-known way, or with the aid of the simplified formula as given above. It must be remarked, however, that the evaporation of the moisture contained in the fuel begins as soon as the temperature of the fuel starts to rise, and is nearly finished when the fuel reaches the temperature of 212 deg. fahr., at which time the last remnants are driven out.

In Fig. 3 lines are drawn to make possible the calculation of losses in cases in which the gases contain CO. The value of A will depend on the amount of carbon burned to CO in relation to the amount burned to CO_2. As one pound of carbon, when burned, gives just as many cubic feet of CO_2 as it would have given of CO, if burned to the latter, the ratio (CO/CO_2) of the two gases present will give the ratio of the two respective quantities of carbon burned to these gases. The lines of constant A will therefore be lines along which the ratios of CO to CO_2 will also be constant.

The amount of heat carried away in the air mixed with the gases will not be contained to the full extent in the excess air if CO is present, as some of this heat will be found in the air that is present in the gases, though not excess air, as it was destined to serve for the combustion of CO. In other words, the air present in the gases consists of two parts: one part of it would be just sufficient to burn the whole contents of CO to CO_2, provided other conditions would be favorable to it; that is, if the gases were heated again to the ignition temperature of CO and properly mixed together; the other part represents the excess air. To calculate the losses through sensible heat carried away in the gases, the total amount of air present in the gases must be taken into consideration. The latter is represented in Fig. 3 by lines marked P running through the points of intersection made by lines E of the same value, and the line CO equals 0, as in the case when there is no CO in the gases the excess air is equal to the total air present.

The loss $L_{(co)}$, due to the fact that some of the carbon was burned to CO only instead of CO_2, will be proportional to the amount of carbon burned incompletely. This is represented by the ratio (CO/CO_2) as shown above, and for this reason the lines of A, along which this ratio is constant, will represent equal values of $L_{(co)}$. The total amount of losses in this case will therefore be—

$$\text{Per cent of loss} = (A + PB)\,(T - t) + C + L_{(co)}$$

B and C depend only on the value of $CO_{2(max.)}$ and are for this reason constants for all cases covered by Fig. 3.

Example. In the case marked on Fig. 3, the per cent loss $= (0.01784 + 0.2 \times 0.01715)\,(T - t) + 5.4 + 5.0$.

Limits of Accuracy

The methods of calculating the losses as given above do not take into consideration the case when oxygen is contained in the fuel in such a form that it will unite with a part of the hydrogen. All coals and some of the fuel oils contain such oxygen, some of them in a quantity sufficient to burn an amount of hydrogen equal in weight to one per cent of the coal. Using a coal of, say, 10,000 B.t.u. heating value, this would mean an error of 6.2 per cent of the loss. For example, if the loss according to the formula above is equal to 15 per cent, the real value of it would amount to 14.07 per cent, as the heat value of the hydrogen, which united with the oxygen of the fuel, has been neglected. However, this is counterbalanced by the fact that this hydrogen increases not only the heating value of the fuel, but also the losses due to the heating and evaporation of water generated. These two neglected quantities keep the balance in ordinary cases. Under the given conditions, if the loss amounts to about 17.5 per cent, there is no error whatever; if the loss however is smaller, the formula will give too low values—for example, instead of 11.4 per cent only 11.0 per cent; but the higher the heating value of the fuel and the lower the percentage of oxygen, the smaller will be the error. When a fuel from a certain region is permanently used, with a permanent ratio of C, H, and O, a special diagram may be drawn, eliminating these errors.

Another constituent in the majority of fuels which will alter the results obtained in flue-gas analysis, is sulphur. One pound of sulphur uses just as much oxygen and also just as much air for combustion as 0.37 lb. of carbon. The hydroxide of potash of the Orsat apparatus absorbs not only the CO_2 produced through burning of carbon, but also the SO_2 formed in consequence of burning the sulphur. Considering this fact, 0.37 lb. sulphur has been added in Fig. 1 to the carbon contained in the fuel, and the diagram gives in reality $(CO_2 + SO_2)_{max.}$ The heating value of sulphur is much lower than that of carbon. On the other hand, when burning one pound of sulphur, not only is less air used than when burning one pound of carbon, but also less gas is formed, although not quite in proportion to the difference of heat values, the heat capacity of one cubic foot of either CO_2 or SO_2 and the 3.76 cu. ft. of nitrogen accompanying each of them in case of perfect combustion being the same. In a practical case, when burning coal containing 75 per cent of carbon and 4 per cent of sulphur with an excess of air which gives 10 per cent of CO_2, 0.2 per cent of SO_2 will be shown in addition in the burette. The latter, however, can not be distinguished from the carbon dioxide, and is taken into calculation as a result of burning carbon, although it was formed through the combustion of sulphur. If the loss calculated on this basis amounted to 18.0 per cent, the real loss would be 18.08 per cent.

No CO_2 was formed from the carbon removed in the ashes and clinkers, but the difference in the losses through heat carried away in the gases will be negligible. If a coal is burned having a heating value of 13,000 B.t.u. and 10 per cent of ashes, and the ashes are removed with a content of 15 per cent of carbon, $T - t$ being equal to 435 deg. fahr., the carbon in the ashes, when burned instead of sifting through the gate, would have represented a loss of 0.138 per cent to be subtracted from L as figured from the diagrams, which are based on the assumption that all the carbon is burned.

The diagrams may be used for natural gas containing not any, or only a little, nitrogen, with an error according to the percentage of this gas, the error increasing in proportion of the content on nitrogen. Producer gas, blast-furnace gas, and the gas coming from a by-product coke oven, containing more or less carbon dioxide, much carbon monoxide, and nitrogen, require, however, special calculations and diagrams, which, once established for a certain type of fuel, may give very good service in the every-day routine in controlling the economic operation of the plant.

The same applies also to fuels in the range of the diagrams as developed above, and the operating engineer will find it advisable, after checking his results based on ultimate analysis of the fuel, to establish corrections for the type of fuel he uses, so as to be able to make up a heat balance based on a proximate analysis precise enough for the needs of the running control of operation, with a knowledge of the range inside of which the error, if any, will fall.

Science and Engineering

A Visualization of the Material Elements of Our Civilization as Complex Products of Manifold Studies, Fundamental and Applied, That Interlock and Trace Back to the Broad, Basic Concepts Through Which We Attempt to Interpret the Phenomena of Nature

By WILLIAM F. DURAND,[1] STANFORD UNIVERSITY, CAL.

WE SHALL all agree, I think, that progress in civilization depends upon putting ourselves more and more fully in partnership with nature and thus working with her as an ally or partner in the utilization of her constructive materials, her energies, and her laws.

If we take any one element of our material progress in civilization and trace out its life history, or, to vary the figure, subject it to some form of qualitative analysis, we shall find that it is the terminal product of a vast number of interconnecting lines of human effort and study, all in a sense converging toward this one end and tracing back in orderly progression to perhaps a widely diversified group of what we term "fundamental" or "basic" facts or laws of nature. It is through these laws of nature, as they work out in terms of application to the intricate and vast field of phenomena, that we are able to come into more effective partnership with her and thus enter more fully into the enjoyment of the treasures which she has laid away in store for us.

But what is a fundamental or basic fact or law of nature? Is it more than the momentarily last stage in our attempt to explain the phenomena of nature in terms of a certain limited number of concepts and relations which we term "basic?" But in this process of observation, classification, comparison, and arrangement in sequence, we never reach the last term. Any so-called explanation is only an expression of relation to some other phenomenon or series of phenomena, and so on without limit. The ultimate explanation always lies beyond, and always will.

We may explain the fall of the apple by gravitation, but who shall explain gravitation? We may explain the color of the sea as due to the passage of light into and out of a colloidal solution, but who shall explain light or the nature of its interaction with a colloidal particle? We may explain water as a chemical combination of hydrogen and oxygen, and we may explain the two-to-nine weight ratio by reference to atomic weights and to valencies, and we may attempt to explain atomic weights and valencies and combining proportions through the properties of protons and electrons; but who shall explain to us the proton and the electron? And if perchance the coming years shall bring an explanation of these, it will only be in terms of some other entities or concepts which will then stand for the moment as the ne plus ultra.

If in any particular case we trace out the derivation from the terminal result back to what seems to be the ultimate source, we shall find the structure as a whole resting upon a formation of so-called basic law, the range of application of which is in no wise limited to the particular and narrow purpose in view. As we pass, however, from this foundation forward toward the terminal result, and along numerous and converging lines, the field of application of the studies which we traverse and of the results which they produce becomes progressively narrowed, until finally all converge upon one single terminal purpose as the ultimate expression of this particular combination of nature's building materials.

Material Elements of Our Civilization Terminal Products of a Converging Series of Studies

It thus appears that any particular facility or material element of our civilization and of which we today enjoy the use, may be viewed as the terminal product of a series of converging studies, each one of which has proceeded from the general to the particular, and all of which are applicable to wider and wider fields of application, the farther back we go from the particular narrow purpose or terminal end from which we start.

Now, largely as a matter of convenience, there has come about the custom of dividing up this one continuous sequence of investigation and study into phases or stages designated by such terms as "scientific" or "fundamental" research, and "engineering," or "engineering and industrial," research. Actually the sequence is continuous and the point at which one type of research ends and another begins, or the proper designation of any one particular study can often be determined only by an act of arbitrary choice. Any research, no matter by what name we may characterize it, is simply an interrogation of nature, and it is only by the use of secondary and perhaps accidental characteristics that we may find some reason for giving to it one name or another.

In our attempts to understand or to explain the phenomena of nature, we have, as I have already pointed out, reached for the moment certain ultimate terms and concepts. Thus with reference to the inorganic world, we attempt to explain the phenomena with which we come into contact through such concepts as center about the terms "time," "space," "mass," "energy," "force," "the ether molecules," "atoms," "electrons," "protons," "quanta," etc., together with the observed relations between and among these various expressions of the objective world. And when any phenomenon is connected through some observed sequence back to these basic concepts it is said to be explained.

Many researches and a noble army of research workers are concerned with this basic field of activity. Some are concerned with efforts to widen our acquaintance with, and understanding of, these basic counters of which I have just spoken; others are engaged in the search for new and still broader generalizations—still more fundamental counters wherewith to explain our explanations; others still are engaged in the attempt to link up through continuous sequences, apparently remote and empirical observations of fact with these present basic counters. All such activities surely merit the designation of "fundamental research," and the body of knowledge which results therefrom is properly called "fundamental science."

We shall all agree, however, that the results of fundamental research stored away as in a granary and never translated into the service of human needs, have failed of realizing their highest use, and that the ideal is and must be that all knowledge of nature should be turned in some way into expression in terms of service to humanity.

To realize this end there must be, therefore, a vast and diversified field of activity dealing with the applications of these results to specific human problems; and so there have grown up the terms of "applied science" and of "applied" or "engineering" or "industrial" research.

In fundamental research the particular application to human problems is not directly within the field of vision. In applied research it necessarily must be. This fact of the presence or absence of some immediate purpose of a utilitarian character, is very commonly made the basis of determination as to whether the research shall receive one designation or the other.

Again, the economic factor is one which bears a distinctly different relation to these two fields of research. Broadly speaking, in fundamental research we do not count the cost of the terminal product. We are seeking for light on the pathways along which nature moves, and when once this particular bit of pathway is illuminated, our goal is achieved. The cost of producing the terminal product is not a factor in this stage of the study.

If, however, results thus achieved are to be translated into the service of humanity, the process must be within economic reach.

It has in fact become almost a commonplace that research and its application to the demands of civilization must pass through the two stages of, first, a laboratory process or research method, serving to establish the broad features or to demonstrate the

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general laws involved, and, second, of studies intended to translate the process from the laboratory to the shop, from something possible under laboratory conditions to something economically feasible under industrial conditions.

We remember when aluminum was well enough known in a small sample way and available by what might be termed "laboratory" processes. It only became possible for aluminum to realize its possibilities as a structural element when the processes became so modified as to place the product within the economic range for structural materials.

Again, helium was once known as belonging in a space in the Mendeljeff series, or again as a substance represented by a line in the solar spectrum. Later it became known in a small way through laboratory processes, but at a cost of production which would have rendered impracticable any economic use, had there been any demand of this character. But with the advent of such a demand as a feature of airship construction during the war, and with the discovery of relatively large sources of supply in our Southwestern gas wells, a combination of physics, thermodynamics, and machine design brought the solution, and helium as a filler for airships has now become an economic possibility. Doubtless other uses will develop.

The domain of technology and industry teems with like illustrations—the refining of crude oil, the development of the steam turbine and of the internal-combustion engine, the manufacture of dyes, explosives, and fertilizers, of toothpicks and matches, and of thousands of other products of industry from needles to steel nails, from window glass to portland cement and pottery, or from writing paper to rubber tires—all have witnessed the same evolution from the laboratory phase, perhaps crude and imperfect and far outside the economic range, through to the final industrial and economic status.

In this process of development and of economic refinement, moreover, it may happen, and in fact very commonly does, that necessary links in the chain are found to be studies or researches which are, in themselves, distinctly fundamental in character. Thus the economical production of helium required the application of advanced and special studies in thermodynamics. Or again, in many of the chemical industries, such as the production of H_2CO_4 or the fixation of nitrogen, the use of catalyzers has developed as a fundamentally important factor. But some understanding of the operation of catalyzers and some basis for their intelligent and efficient use is only now coming into the light, resulting from studies on the firing line of advanced theory regarding the structure of the atom. Or again, engineering or industrial studies looking toward the development of the most efficient design of devices for securing the interchange of heat between liquids, gases, and vapors separated by metal partitions, are attracting much attention in recent years. Such studies, for their effective prosecution, call upon theories of steam flow, of turbulence and its nature, of the mechanism of heat transfer from one molecule to another, and thence to the most recent theories of the constitution of the molecule and of the atom.

Fundamental vs. Industrial Research

And so on every hand, studies in which the economical factor is paramount and in which the direct purpose is industrial rather than fundamental, include as essential features, researches and studies which in themselves are distinctly basic in character. And so in the pursuit of any one purpose, stated in industrial terms, there may be found researches and studies in the most diverse fields, and of all types as regards status, from the most thoroughly fundamental to the purely industrial—and all as essential elements in the program of development.

Again, in many cases of research the question asked or the end in view may be of a purely empirical or observational character, perhaps without reference to any useful applications, and likewise without relation to any sequence carrying back to what I have termed our "fundamental counters." It is often of the highest importance that the answers to questions of this character be determined at the earliest practicable moment, leaving to other times or to other agencies the task of connecting them up with more fundamental concepts. In other cases such empirical results are set down simply as so much material, without reference to utilization or terminal purpose, but simply as classified observation, awaiting the time when in adequate amount it may serve as a means for reasoning from such empirical results back to some earlier stage in the sequence leading to the ultimate counters.

But these various interrogations of nature, no matter what the particular relation to their environment, are of the essence of research, and their results constitute the great body of science viewed as a whole. Broadly, we may say that in proportion as the study deals with the phenomena of nature with more remote reference to specific purposes or applications, to such extent is the research the more fundamental in character; and in proportion as it is more narrowly focused on a single or utilitarian purpose, to such extent does it more definitely belong in the engineering or industrial category.

But the important point is not by what name we shall call a given research, but rather to recognize the fact that all types and forms find their place and serve their purpose as essential elements in our continuous approach toward nature and a better understanding of her ways.

If fundamental research is to realize its measure of service to the cause of human progress, it can only do so as it is carried on to useful application through specific studies directed to that end. It is no less true that in our efforts to ally ourselves with nature and to seek from her wherewith to answer the many needs of our modern civilization, we should find ourselves in a blind path without these more fundamental studies to light the way.

Engineering and industrial research are thus indissolubly tied in with fundamental research as a starting point. And these two phases of research are after all only the two indivisible parts of a single procedure which leads us from nature and her infinite complexity of orderly sequence down through to the most humble and simple application to the needs of humanity in its progress along a rising gradient of civilization.

Illustrations Showing the Dependence of Applied Science upon Fundamental Science

At this point, perhaps, some further illustrations may be of use, not in detail but only by way of mere mention, and only in order the better to bring out the intimate dependence of applied science upon fundamental science or otherwise to show the manner in which the results of such fundamental research works through to its goal in terms of useful application to human needs.

In selecting such illustrations, the principal trouble is with the wealth of material. There is, indeed, an embarrassment of riches, and in selecting here and there I shall choose only at random from some of the arbitrary subdivisions into which we partition the field of scientific work.

If we take first that most exact of the sciences, mathematics, we have the foundation of all quantitative measurement and comparison as used throughout the whole domain of engineering and industry. What, again, of logarithms and their expression in the slide rule—that tried and trusty friend of the engineer?

Or again, what of the theory of dimensions, dimensional analysis, and the principles of similitude? The entire art of shipbuilding as a field of engineering and industry is dependent, so far as the determination of matters relating to resistance and propulsion are concerned, upon the application of experimental methods which rest upon these mathematical cornerstones. The same is true of aircraft resistance and propulsion, as well as of many other parts of the domain of engineering and industry where these principles, developed and contributed by the mathematician, furnish a most valuable and indeed a necessary element in the treatment of the problem involved.

Or still again, what of the theory of elasticity and its development at the hands of a long line of illustrious mathematicians? The entire theory of structures and the practice in structural engineering trace for their foundation back to principles which have their roots deep in the physical properties of matter as developed, interpreted, and applied through the aid of mathematics and the labor of mathematicians.

If we turn to another type of illustration, what of Carnot and his immortal principle, or of Fourier and his equally immortal series?

The whole domain of power from heat rests for its economic realization on the principle laid down by Carnot and developed as

the product of his own penetrating insight into the laws which nature has laid upon herself in regard to the transformation of heat energy into mechanical work.

It is perhaps doubtful if in the domain of science and engineering there is to be found a more striking example of far-reaching application to the progress of civilization than this product of pure reasoning in the brain of Carnot. The very name of his paper suggests its source in his own mind—"Reflections"—reflections on the motive power of heat.

Again, its seems like a long step between the foretelling of the rise and fall of the tide with such a degree of reliability and precision as to tell just when the commerce of the world may enter our harbors and when it may not, and the investigation of the phenomena of the flow of heat along a metal bar. But all of this and much more has come out of Fourier's classic researches on the latter problem.

Again, in this same domain of heat there are perhaps no problems of greater practical importance than those which relate fundamentally to the transmission of heat from a molecule of one kind to another molecule of a different kind. On this basic problem depend all manner of industrial operations involving the use of heat—steam boilers, condensers, coolers, heaters, heat exchangers of all sorts and for realizing an exchange of heat between solids, liquids, gases, and vapors, in all combinations and in infinite variety of applications in the arts and industries. But the intelligent study of these problems, in their terminal applications, all traces back to fundamental problems in physics, and in particular to the mechanism of the exchange of heat energy between molecules of different kinds and at different temperature levels. Any effective study of the terminal problems and their application in the arts and industries is dependent on these fundamental studies; and on the other hand, such studies into the structure of matter and the properties of molecules, leading as they must into the modern electron theory of the constitution of the atom, find some of their most useful applications in industries in pointing the way to a better understanding of the conditions which surround this problem of the transfer of heat energy from one molecule to another.

If we take an illustration from the field of metallurgy, we cannot perhaps find a better one than that furnished by the recent developments in the study of metal crystals and crystal aggregates, as bearing on the physical properties of metals, especially strength, yield point, and hardness.

These fundamental researches have thrown in recent times a flood of light on hitherto most obscure phenomena relative to the properties of metals, and promise ultimately to furnish some measurably satisfactory explanation of the intricate conditions affecting the tempering and hardening of such aggregates as steel and duralumin.

In a high sense, furthermore, these investigations are fundamental since they are not merely the empirical expression of observation, but seek rather to develop an explanation through a study of the relation between the observed terminal phenomena and certain other more basic conditions expressed in terms of crystal structure, and so on in sequence back to fundamental concepts.

The field of chemistry is especially rich in material illustrative of the close dependence of industrial research, as expressed in terms of terminal products, upon fundamental chemical research. To mention only a few, what of fertilizers and explosives, synthetic fuels, synthetic drugs, synthetic silk and now wool and perhaps rubber, the dye industry, paints and varnishes, and like materials? The industrial production of substances such as these traces back to fundamental chemical research as its absolutely essential point of departure.

CONTRIBUTIONS OF PHYSIOLOGY, PSYCHOLOGY, AND SOCIOLOGY TO INDUSTRY AND PRODUCTION

But it is not alone in the so-called "physical" sciences that we find the foundations of our progress in the arts and industries. Psychology and sociology both contribute through the aid which they furnish in reaching a better understanding of the human element as expressed in what we term "labor." Psychology in its more modern expression helps to fit the right man to the job; sociology helps to point the way to better human relations, and hence better productive efficiency in the fields of human industry.

Again, in the whole domain of industry there is, perhaps, no more important problem than that of waste and loss through human fatigue. In conversation with a thoughtful economist recently, human fatigue was instanced as one of the greatest and perhaps the very greatest cause of loss, inefficiency, and waste in all forms of human endeavor.

It is fatigue expressed in terms of wandering attention which leads the engineer to read his slide rule incorrectly. It is like fatigue which causes countless numerical errors in quantitative readings and manipulations in all forms of human activity. It is fatigue which slows up production, or still worse, which leads to errors, false moves, wrong assemblies, inaccurate dimensions, a rejected product, and thus waste and loss.

But fatigue is a physiological phenomenon and its study is a physiological problem, and no adequate examination of the influence of fatigue on industry and industrial production can be made except through the aid of this branch of biological science. We have in this instance a striking illustration of the direct dependence of engineering and industry upon researches in a science which, at first sight, seems the most remote from that in which its results are to be applied.

AERONAUTIC ENGINEERING A FIELD WELL ILLUSTRATING THE ESSENTIAL UNITY THAT MUST CHARACTERIZE ALL RESEARCH WORK

By way of another illustration, let me turn your attention to the field of aeronautics and aeronautic engineering. This happens to be a field in which my own interests have been engaged in recent years, and perhaps for that reason it seems to me to furnish a peculiarly good illustration of that essential unity which must characterize all research work, no matter by what particular name it may be called.

The development of the airplane has resulted through the convergence of three measurably distinct lines of research and study. There is first the field of aerodynamics which deals with the airplane in relation to its sustentation, movement, and behavior in the air; and then there is the field of structural engineering, including the theory of structures in its most refined and complete form; and then again the field of thermodynamics and heat engineering which deals with the ways and means of converting heat energy liberated from liquid fuels into the mechanical work required for propulsion—and all under the limitations of weight and size imposed by the conditions of airplane flight.

We have here at the foundation, mathematics, physics, fluid mechanics, rigid structures and their mechanics, thermodynamics, and chemistry in its relation to many problems of glues, dopes, varnishes, anti-knock fuels, etc. And over and throughout this entire field there have been studies which are truly fundamental in character, serving as stepping stones again for others more immediately related to the airplane as a terminal result, and so continuously focusing more and more directly upon the ultimate goal—the realization of a structure which, supplied with a source of energy, shall, under human control and direction, be able to rise from the ground, move as may be desired in the air, and return again to the earth.

Running throughout this complex of research and study is the continuous demonstration of the extent to which progress toward any one specific goal may require the widest variety of seemingly remote and fundamental studies. As one illustration, the problem of the liquid-fuel-injection engine as adapted to aircraft requirements has for some time been the subject of study. One of the earliest phases of this study has related to ways and means of obtaining a photographic history of the formation and progressive development of a jet of liquid when forced under high pressure through a small aperture. This required an extended and independent study of rapid-motion photography with time exposures infinitesimal in extent. Other problems have related to the mechanics of the formation and flow of periodic jets of liquid through orifices of different form and in the brief time available as a small fraction of the cycle of a high-speed engine of the aircraft type; still others have related to the character of the combustion of such jets and the conditions affecting the progress of flame through them. Again, other needful studies have related to matters bearing on the types of mechanism best suited to meet the particular combination of requirements presented, and still other to matters of design, structural materials, etc.

Certain of these studies are essentially fundamental in character while others are directly focused on specific objectives, but all are essential, and the terminal result is simply the joint product of this complex series of studies, each one of which has contributed some element to the realization of the ultimate goal.

One further illustration in a different field will again show the same interdependence. The law of kinematic similitude, if perfectly realized, permits the determination of the resistance and other conditions of movement in the case of a full-sized body moving relative to a fluid through the use of a small model, geometrically similar and moving with a velocity as determined by the law of similitude. But in the case of airplane structures and air as the fluid, the conditions of similitude can rarely be met. For a small model the velocities become too high for practical realization. It thus results that with small models in normal air there is need of a correction known as the "scale factor" and intended to make up for this lack of fulfilment of the requirements for complete similitude. But the evaluation of such a factor is attended with much difficulty, and to the degree to which the conditions of complete similitude can be approached, to such extent will uncertainty be removed.

Now one method by which these conditions may be more nearly realized is by the use of air under an increased pressure and density instead of air under normal atmospheric conditions. In such case the spacing of the molecules of air in relation to the dimensions of the model may be made similar to that of the molecules of free air in relation to the dimensions of the full-sized body, and thus at workable velocities the conditions of similitude may be realized.

In order to make use of these principles, an air tunnel inclosed in a steel shell and intended for the use of a current of air under high pressure and density has been designed and installed in the laboratory of the National Advisory Committee for Aeronautics at Langley Field, Va., and with this equipment a wide range of research has been carried on, in part broadly fundamental and intended to develop a better understanding of the basic phenomena attending the movement of a solid within a fluid, and in part more immediately directed toward the solution of specific problems in aeronautic engineering.

The design and construction of this piece of laboratory equipment in itself, again, called for the widest variety of investigation into special problems in physics, in the theory of elasticity as applied to structures, and in design and construction.

But if to reach any specific goal, research of varied types must coöperate and interlock, and if, as in many of the preceding illustrations, applied research is continually falling back on phases of fundamental research, it is none the less true that the latter, for its tools and implements, its ways and means, is as continually falling back on applied research and its results. A single illustration will suffice.

A recent visit to the Bureau of Standards in Washington gave opportunity to examine the piece of equipment which is to serve for a really monumental research on the properties of water vapor up to pressures of perhaps 80 atmospheres.

Thus far and for two years and more the work has been concerned with the construction of the apparatus—with searches for suitable materials of construction, with the design of valves and joints, with the study of methods for preventing or minimizing leakage—material, thermal, and electrical. Thus far the research has been wholly in the applied field. With the apparatus completed, the final and fundamental stage will be ushered in.

Illustrations beyond number of this essential interlocking of all types of research may be drawn from any or from all of the fields of activity of the scientist and of the engineer.

CONCLUSION

I have thus attempted to visualize the material elements of our civilization, as complex products of manifold studies, fundamental and applied, interlocking, and tracing back ultimately to the broad and fundamental concepts, through which, for the moment, we attempt to interpret the phenomena of nature. Those studies deal with nature in all her aspects and from all avenues of approach. Some deal with what I have called our "basic counters" or with the linking up of observed phenomena with such counters. Others deal more directly with terminal results, and in an immediate or observational way. If we may look upon these various studies and their results as building blocks, then out of this building material we have builded, in almost infinite variety of combination, the terminal products which go to make up the material content of our civilization.

If we seek to compare these two types of building material as they have entered into any one terminal product, or to ask which of the two is the more important, there is no answer to the query. Both are essential as we have seen.

But if we are thinking in terms of progress, if now and hitherto unknown results are to be realized, then *new* building material must be available, and in the way of such new material we shall agree, I believe, that the products of basic or fundamental research are of greater significance than those resulting from more narrowly focused studies. It is more valuable for us to have some knowledge of the crystalline aggregates which go to make up steel as a basis for explaining its properties, than to record the fact that plunging red-hot steel into water will harden it. It is more important for us to have some working theory of the conduction of electricity in metals than to merely know that copper is a better conductor than iron. It is more important to have some working theory of the molecular constitution of metals and of the results thereon of repeated stress, than to merely record the number of million times any particular sample may withstand a particular repetition of stress before rupture.

A new basic relation in nature, a new linking up of observed phenomena with our basic counters, may open up an entirely new series of practical and useful results. It constitutes a new source, available for use in combination with all other known sources, and with vast and unknown potentialities for useful application.

If, then, we are to carry on along an ascending gradient of human progress, we must look to the provision of new building material or, to vary the figure, of new sources of basic knowledge. Without such, the streams of progress will become dried at the source. Without such continued activity as a nation, we shall be left behind in the world condition.

It perhaps runs with the so-called practical character of our genius, that as a nation our contribution to world progress has lain thus far more largely along lines of applied science than along those more fundamental in character. In the former lines of research and achievement we have made a record in reasonable relation to our endowments and our opportunities. It is not clear that we have made or are making a like record along the latter lines.

As a nation we are spending, year by year, in one form or another, sums which bulk to enormous magnitudes for research along lines of engineering and industrial research. We are not supporting in like proportionate degree research along more fundamental lines. We are cultivating the lower reaches of flowing stream and quiet pool, and, at least in relative degree, we are neglecting the living sources nearer the mountain tops. A more just balance is needed in the support which we are giving to these two lines of effort.

If we view the matter simply as a question of duty, duty to the world at large, duty to coming generations, duty as trustees of a present deposit of civilization placed in our hands for a brief period and which we are to pass on with such increment as we may; from whatever aspect we may view the question as one of duty, the pathway seems clear. The world at large has the right to look to us, with our industrial progress and prosperity, for some larger measure of support for research calculated to add to our stores of fundamental knowledge.

Or otherwise if we look at the matter from the narrower viewpoint of self-interest or expediency, the same conclusion is obvious. We must provide new building material, new elements of combination. We cannot afford to depend indefinitely on our present stock or to wait for others to supply us with new.

The call of duty is the higher appeal. Only by a sense of duty well done we face calmly the judgment of future ages regarding the use which we have made of the deposit of civilization placed in our hands for a few brief years, and especially regarding the extent to which we have added some increment of our own as a contribution to the cause of human progress.

Hydraulic Maintenance at Holtwood Plant

Conditions Causing Deterioration of Hydraulic Turbines—Overcoming Effects of Corrosion—Thrust Bearings—Maintenance of Turbines and Governors—Pitting of Runners—Safe Practices During Turbine Repairs—Governor Control System—Inspections

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THE purpose of this paper is to discuss the procedure and methods of hydraulic maintenance in the Holtwood 150,000-hp. hydroelectric development located in Pennsylvania on the Susquehanna River.

A careful survey of various technical publications discloses that very little information on this subject has appeared in print. This is most likely due to the many different designs of turbine equipment in use and to the fact that this is usually considered a local problem, having little application in other hydro stations.

Hydraulic turbines, especially the earlier types of vertical double-runner units to which particular attention will be given in this paper, have a large number of operating-mechanism parts which are always subjected to progressive deterioration or wear, and which cannot conveniently and economically be kept in perfect condition. The wear and deterioration must be permitted to progress to that point where it is economical to replace the wearing parts, and yet it must not be permitted to progress so far as to interfere with the output of the unit or endanger its continued operation.

Conditions Causing Deterioration of Hydraulic Turbines

Corrosion. It may be of interest to explain that the Susquehanna River and its tributaries drain and pass through the anthracite coal-mining districts of northern Pennsylvania. Before the coal is ready for the market it is washed; this process requires large quantities of water, the result being that all the dust and finer particles of coal are washed into the river and the water becomes highly charged with sulphur. It is this sulphuric content, in addition to the waste products from factories and sewerage of many cities that discharge into the river, containing corrosive acids, which causes trouble. The percentage of sulphuric acid radicals in the water is greatest in the low-flow season of the year, and at its minimum during high flow.

Unprotected iron and steel parts submerged in the river water are quickly attacked. The resulting corrosion eats away the parts, reducing cross-section and strength.

Silt. During approximately three months of a normal year, at different periods such as the breaking up of the winter ice formation, spring freshets, and floods after heavy rains, the river water contains an enormous amount of fine particles of silt and sand. The presence of large quantities of grit in the water causes very rapid wear of the various close-fitting bearings, pins, and bushings, regardless of the materials from which they are made.

Mechanical Failures. Troubles from this source can generally be traced to three different causes: first, flaws in castings and forgings; second, corrosion weakening the metal sufficiently to cause failure; and third, heavy obstructions floating in the river and entering the penstocks when the intake screens are raised preparatory to or during a run of frazil ice.

Pitting or Cavitation of Turbine Runners. This trouble and methods of repairs will be explained later in the paper.

Progressive Deterioration of Hydraulic Equipment and Corrective Measures Developed in 15 years of Service

Turbine Equipment. A brief history of the hydraulic installation will be outlined. The design, manufacture, and installation of the entire hydraulic equipment were carried out by the I. P. Morris Co., now a department of the Wm. Cramp & Sons Ship & Engine Building Co. of Philadelphia, Pa.

The designs for the first five 13,500-hp. turbines were completed early in 1907, although on account of the failure of the McCall Ferry Power Co. they were not installed until about four years later. They are of the vertical double-runner type with submerged operating mechanism. The two 1000-hp. single-runner exciter turbines were also designed at this time.

The designs for next two 17,000-hp. turbines (Fig. 1) were completed in 1912. These units are essentially the same as the first five, but with improvements in the operating mechanism which were incorporated as the result of the difficulties experienced with the earlier design.

The No. 8 unit, the first modern single-runner type of turbine in the station, was installed in 1914. The most marked improvement over the earlier types is the location of the operating mechanism, which is not submerged but located directly on top of the turbine head cover, easily accessible for inspection, lubrication, and repair.

In units Nos. 9 and 10 (Fig. 2), which were installed in 1923, there are incorporated many refinements over No. 8, the operating mechanism being essentially the same. The Moody spiral spreading draft tube with center cone rising to the runner cap is the outstanding feature of these two units.

First Troubles, 1911. The first of the original five units installed was put in commercial service in October, 1910, and the others followed at two-month intervals. It would make a long report to attempt to relate the many difficulties encountered and overcome in the first year of the operation of the plant. Both from an operating and maintenance standpoint, the many untried innovations were the cause of much concern and required considerable pioneering until reliable operation was obtained.

Trouble from corrosion became evident in the first unit after a few months of service. The cast-steel operating rings which actuate the guide vanes through links had not been provided with brass liners on the bearing or contact surface with the cast-iron supporting or guide-ring segments. The latter also had no brass liners attached on the horizontal and vertical facing to ease the turning movement of the operating rings. The steel links which transmit the movement to the vanes from the operating rings had no brass bushings in the two steel-pin connections. These pin connections had a neat fit, there being 80 connections to each runner or a total of 160 on each unit. As would be expected, considerable corrosion took place at these points and added greatly to the friction of the mechanism.

The guide vanes, which are held in position and turn axially on steel fulcrum pins, were not provided with any lubricating facilities whatever, the bore in the guide vane being free to turn on the pin, with but small clearance. It can readily be seen that corrosion of these bearing parts greatly increased the contact friction to such an extent that in time it would be impossible to move the mechanism, much less obtain satisfactory governor regulation.

The movement of the operating mechanism became extremely sluggish and required that the governor fluid pressure be gradually increased from 125 to 250 lb. to obtain control of the unit. The time interval required for gradually increasing the pressure according to the increase in the friction resistance of the moving parts was approximately one and one-half years.

The troubles to be overcome were of design rather than of maintenance, but the two became so closely related that the company's maintenance program had an early start. During the installation of the following units, certain modifications and improvements to the operating mechanisms were readily incorporated without any material changes in design. These improvements consisted of the addition of non-corrosive metals on the bearing surfaces and pin connections of the operating mechanism.

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[1] Chief Operator of Holtwood Plant of the Pennsylvania Water & Power Co.

Presented at a meeting of the Baltimore Section of The American Society of Mechanical Engineers, Baltimore, Md., November 21, 1925.

MAINTENANCE OF TURBINES

As previously stated, the original problem was to overcome the effects of corrosion. This was accomplished as follows and detailed in Fig. 3:

1 By attaching brass liners to the operating and guide rings
2 By inserting brass bushings in both pin holes of the vane links
3 By reducing the bearing surface of the fulcrum pin to a minimum, having contact with the vanes at top and bottom only
4 By making provisions to force grease through the fulcrum pin, and fill the recessed space between fulcrum pin and vane bore
5 By attaching bushings to fulcrum pins and into bore of vanes at both top and bottom.

These modifications or improvements solved the problem of reducing the friction in the operating mechanism, permitting satisfactory regulation.

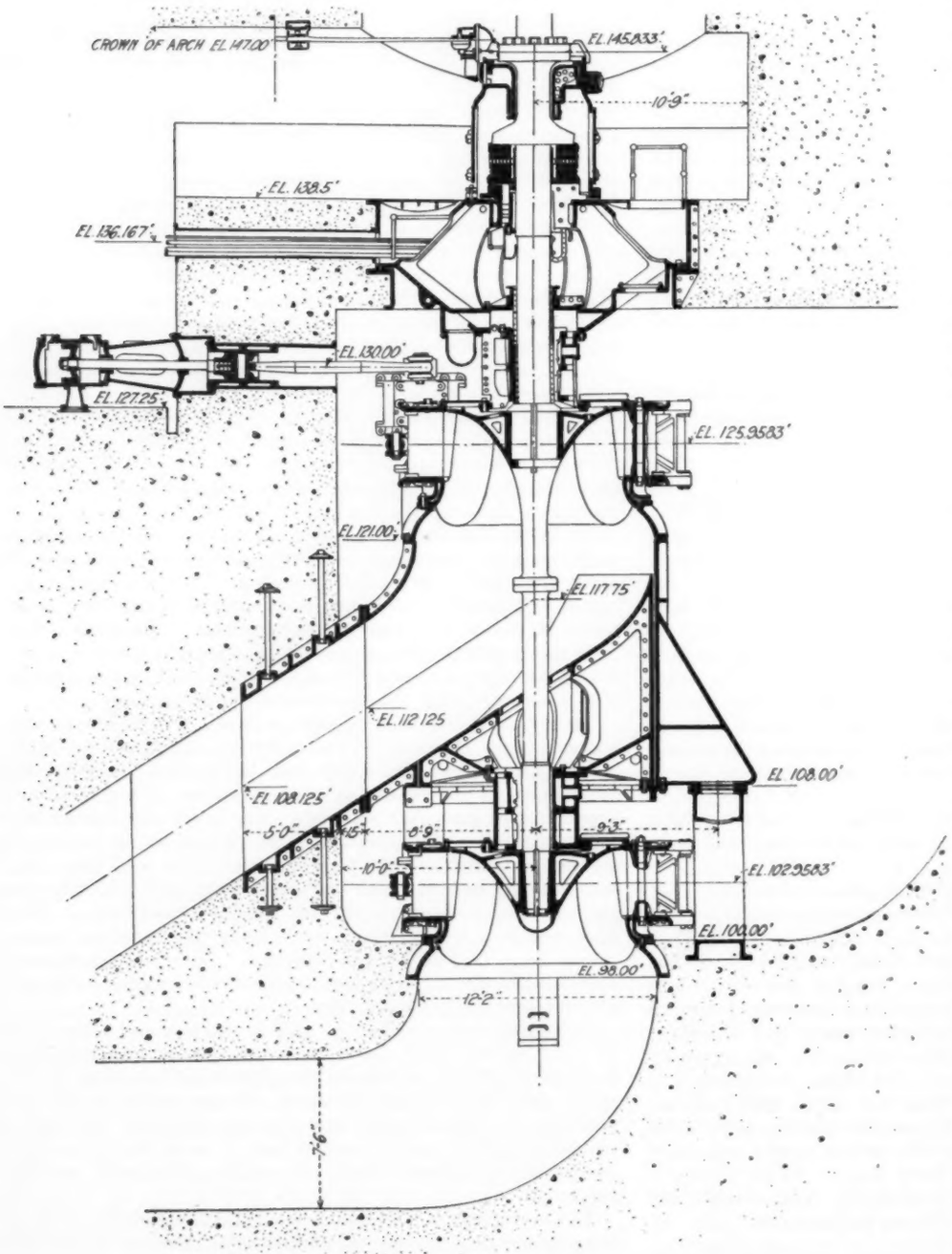

FIG. 1 GENERAL ARRANGEMENT OF A 17,000-HP. DOUBLE-RUNNER TURBINE

Pins. The next problem was to eliminate as much as possible the frequent renewals of the steel pins for the connecting rod, operating rods, and links.

The combined influences of corrosion and the fine particles of grit in the water caused rapid wear of these pins, reducing their respective diameters approximately $^1/_{16}$ in. per year and causing so much lost motion in the mechanism that in two years the vanes would not close tight and full gate opening was restricted sufficiently to cause a reduction of 300 to 400 kw. in the capacity of unit. Certain modifications were made to the connecting- and operating-rod pins, but without success.

Monel metal, having well-known non-corrosive qualities, was in 1915 substituted for steel pins. The large-pin experiments were unsuccessful, apparently due to the softness of metal. The smaller monel-metal link pins were successful, principally due to the stresses being distributed to 160 pin connections, whereas there are only ten large pins in the heavier mechanism. The monel-metal link pins were first put in No. 1 turbine in 1915 and after ten years' service are worn only 0.004 to 0.006 in. undersize, and will have many more years of service before replacement.

Machine-steel pins were again in 1918 substituted for the large monel-metal pins after the failure of the latter. The change was a slight improvement, but the steel corroded rapidly.

Several years ago "Ascoloy" metal, an electric-furnace product which resists corrosion and abrasion and is 50 per cent stronger than steel, was given a trial. Large pins were made from this metal for the connecting- and operating-rod connections, which to date indicate no appreciable wear and show no tendency whatever to corrode, retaining the original bright finish on the exposed parts.

Lubrication of Pins. The failure of the large monel-metal pins brought about what it had been hoped could be avoided, i.e., the installation of pin-lubricating equipment for each turbine. This equipment, which is located on the generator floor and is manually operated, has nine separate pipes leading from the grease gun to each of the large pins. The grease-piping arrangement for a double-runner turbine is shown in Fig. 4. This lubrication of the steel pins extended their life from two to six years The substitution of "Ascoloy" metal for steel should increase the life to ten or twelve years, before replacement is necessary.

A heavy oil (winter gear oil) is used, having the desired viscosity to flow under pressure through $^1/_2$ in. pipes when the water temperature in summer is 25 deg. cent. and in winter 0 deg. cent. Considerable experimenting covering several years with different lubricants was necessary before the proper grade was obtained that would flow through as much as 50 ft. of $^1/_2$-in. pipe under minimum water temperatures.

Guide Vanes and Fulcrum Pins. Corrosion and grit also caused excessive wear on the fulcrum pins and in the bore of vanes, resulting in as much as $^1/_4$ in. lost motion, preventing the closing of vanes and likewise full gate opening. This condition is being improved as opportunity permits by equipping the vanes and pins with bronze bushings which, when enlarged, can be replaced with new parts. These improvements are also of such value as to defer repairs to these parts for a period of twenty years. Incidentally, the recessed space between the vanes and fulcrum pins is filled at five-year intervals with a heavy semi-fluid adhesive grease known as "Hydraulic Lubricating and Coating Compound."

Operating and Guide-Ring Liners. Since the large steel pins were at first the most frequently renewed parts in the operating mechanism, they determined the interval between overhaulings. After correction of this trouble further studies were made of metals to replace the $^1/_4$-in.-thick brass liners on the operating rings and guide-ring segments, which usually were completely worn out in five to six years. It is important that these liners be replaced before worn through, as the operating rings would be lowered sufficiently to come in contact and obstruct the movement of the vanes, restricting the full opening to approximately 70 per cent.

A composition cast metal known as "Demaxine," resembling brass and possessing inherent lubricating qualities, was substituted for brass, and after eight years of service showed no appreciable wear. Instead of brass liners on both the operating and guide rings, $^1/_2$-in.-thick "Demaxine" liners were attached to the operating rings only, and the brass liners were removed from the cast-iron guide-ring segments. The latter were lowered by $^1/_4$-in. thick shims to compensate for the $^1/_2$-in. liners on the operating rings. The absence of positive lubrication other than water on these extensive bearing or contact surfaces of "Demaxine" metal on cast iron is a very desirable combination, and is of such value as will most likely defer renewals of these parts to at least every 15 years, whereas the brass liners were completely worn out in 5 years.

Incidentally, it may be of interest to mention that all renewable parts of turbine equipment are stamped as to name of metal, designation, and date installed.

Benefits of Improvements to Operating Mechanism. The following tabulation indicates the amount of force necessary to exert on the piston head of the operating engine to move the submerged mechanism before and after improvements were incorporated.

Year	Condition of mechanism	Force to move operating mechanism at 50 per cent gate opening, lb.
1912	Badly corroded	65,000
1918	Good condition. Wearing parts provided with brass liners and bushings	13,700
1925	Good condition. "Demaxine" metal substituted for brass liners and other minor modifications	9,500

The reduction in the energy required to move the mechanism is very marked, and has been advantageous in greatly improving the governor regulation of units.

Painting of Turbines. During the first five years of the operation of the plant, numerous experiments with various paints and enamels were made to minimize the corrosive effects of the water on the submerged turbine castings, none of which, however, can be said to have been entirely successful.

Red lead mixed with equal parts of linseed oil and "Flexible Compound" applied in two coats has been found the most durable for the turbine parts. After ten years of service the red lead can be found in a fairly good state of preservation under a very hard incrustation that forms on the metal parts on top of the paint. However, the company has never been successful with any paint or enamel applications on parts such as the guide vanes or on the runner where the water impinges directly, for more than a few months. In spite of the lack of a protective coating on these parts there is remarkably little corrosion, excepting on the areas affected by pitting.

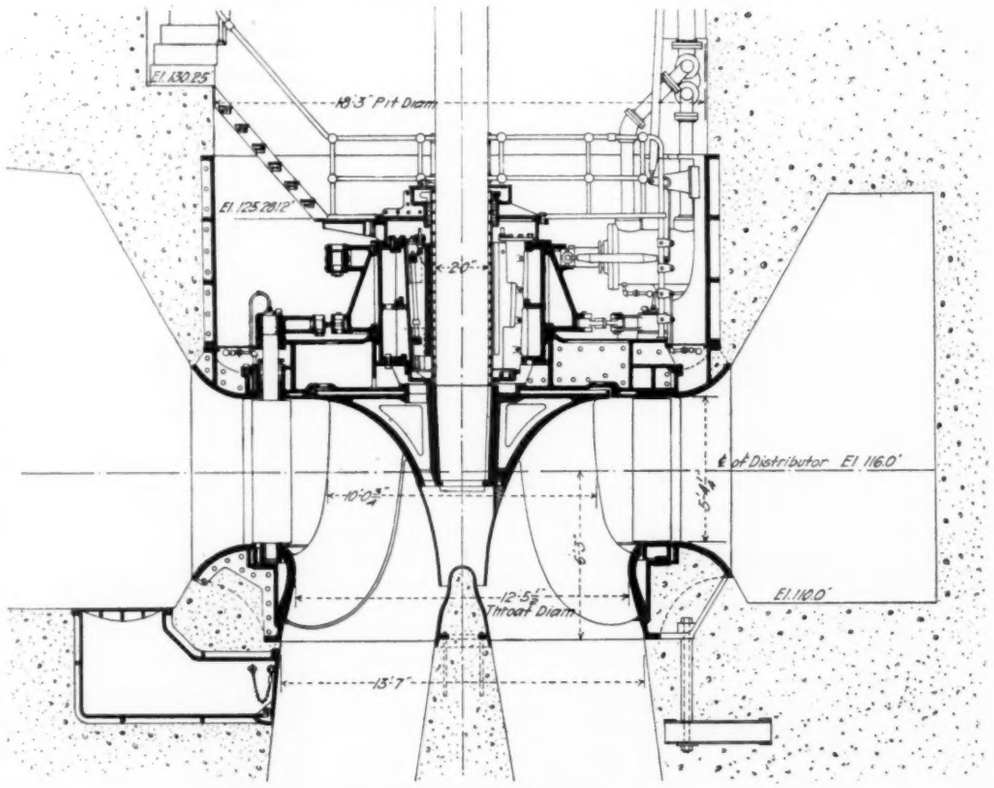

FIG. 2 GENERAL ARRANGEMENT OF A 20,000-HP. SINGLE-RUNNER TURBINE

The painting of these large turbines is a rather big job, requiring considerable labor to first clean the parts with wire brushes. Cleaning with sand blast is the better method, but has the disadvantage of requiring the complete dismantling of the entire operating mechanism to prevent sand from lodging in the many link-pin and bearing connections.

Guide Bearings for Double-Runner Units. All of the double-runner turbines have three guide bearings. The upper is oil-lubricated; the other two are of the submerged lignum-vitae barrel type. The single-runner turbines have but one guide bearing, which is of the lignum-vitae type.

The lignum-vitae bearings in the double-runner units are large, heavy, and are not easily accessible, and are lubricated entirely by water taken directly from the wheel pit.

The presence of vast quantities of sand and silt in the water causes the lignum vitae to wear or enlarge rapidly. Also the shaft journal, which is a bronze sleeve, wears slightly undersize. This action causes the runner band (runner seals) to come in contact with the distributor rings, wearing these parts sufficiently to cause considerable leakage and loss of output.

During the prolonged spring freshets and floods, which carry enormous amounts of sediment, these bearings receive very severe treatment and enlarge rapidly, most especially the lower bearing,

which, when slightly enlarged, permits the shaft to swing or turn eccentrically due to unequal water thrust in the runner. The eccentric motion of the shaft causes a continuous pounding of the lignum-vitae lining and accelerates wear. This action also has a tendency to permanently wear the shaft journal eccentric, and subsequent bearing renewals are more frequent than if the journal was true.

Coarse-mesh screens are provided to prevent leaves, sticks, etc., from entering the bearings while passing the finer particles. Should close-mesh screening be used, it would become entirely obstructed and stop the flow of water.

Bearing Renewals—Double-Runner Units. The upper lignum-vitae bearing is replaced approximately every twelve years, when

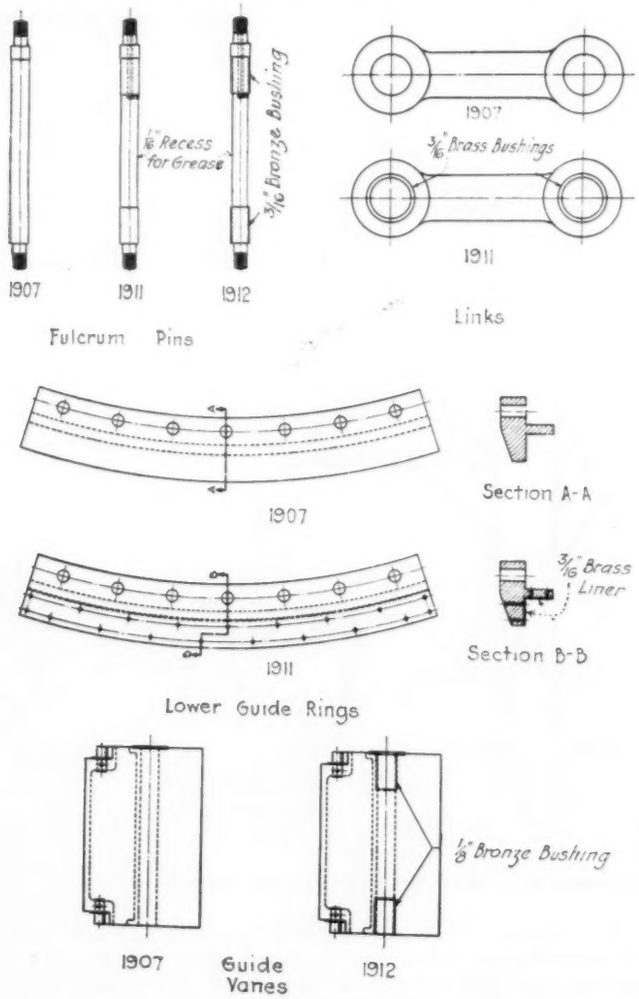

FIG. 3 ALTERATIONS TO TURBINE OPERATING PARTS

usually there is an enlargement of slightly more than $^1/_{32}$ in. The lower bearings now require replacement every three to four years and are usually enlarged $^1/_8$ in. In fact, several of them have required replacement every two years.

Single-Runner-Turbine Guide Bearings. The bearing in the No. 8 single-runner turbine is considerably larger than either of the bearings of the double-runner units. Water lubrication is taken directly from what is known as the forebay (river water) header. A $^3/_4$-in.-mesh screening is provided for the header, and a fine close mesh at the supply to the bearing. Despite the double screening, rapid wear of the lignum-vitae lining is caused by silt in water.

The type of bearing in each of the No. 9 and No. 10 turbines is a decided improvement over the type in the older units, each bearing having four adjustable shoes or segments. This feature permits adjusting the shoes to take care of the wear.

Renewals of Single-Runner Bearings. The No. 8 turbine bearing has had an unfavorable record. It was put in service in 1914 and to date has been renewed eight times, each bearing averaging one and one-half years' service.

The adjustable feature of the Nos. 9 and 10 turbine bearings will permit approximately three years' service, after which time the shoes must be reblocked with lignum vitae.

Exciter-Turbine Guide Bearings. These units are of the single-runner type. Each has one oil-lubricated and one submerged lignum-vitae bearing. The latter have required more renewals than the bearings in the double-runner units. The service has been so severe as to require two renewals of the bronze sleeves on shaft. The installation of water strainers, which are periodically cleaned, has improved conditions somewhat.

Experimental Rubber Bearing. In view of the difficulties that have been experienced with the lignum-vitae bearings, the use of rubber-lined bearings as applied to ship propellers occurred to the author as applicable to large vertical hydraulic turbines.

The manufacturers were consulted as to the feasibility of the application, and they considered it worth a trial in one of the 1000-hp. exciter turbines. Instead of casting a new bearing shell, a spare bearing was modified only in the internal bore by a coarse thread and the rubber vulcanized in place. After the rubber was vulcanized it was ground to size, and the spiral grooves for the lubricating water ground into the bearing. The bore of this bearing

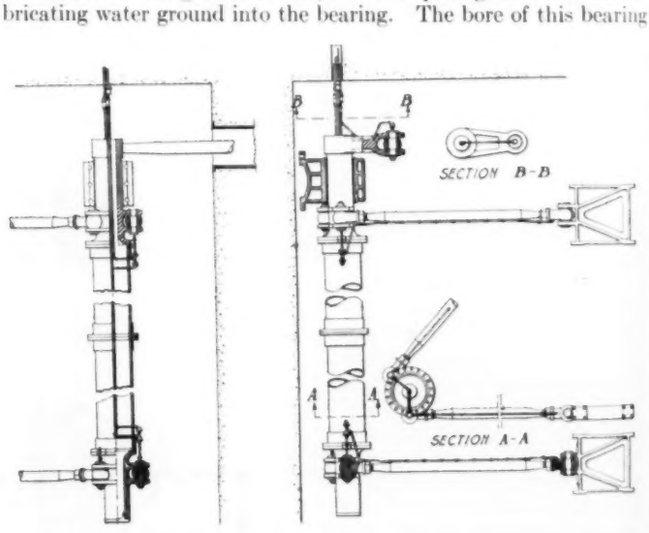

FIG. 4 GREASE-PIPING ARRANGEMENT FOR DOUBLE-RUNNER TURBINE

(Fig. 5) is 9 in. and is 2 ft. 6 in. long. The speed of the shaft is 240 r.p.m.

This trial installation was made in November, 1924, and has been in continuous service for one year with very satisfactory results. The rubber continues to be in an excellent state of preservation, showing no signs of deterioration and appearing to have the same degree of resilience as when first installed. This bearing has undergone a very severe test, as during the prolonged spring floods of this year the river water, by which this bearing is lubricated, carried a greater amount of sediment than during any other like period since the hydro plant has been in operation.

It would be premature at this early date to draw a conclusion as to the probable life of this or similar applications of rubber to large vertical-turbine bearings, as this is the first instance where this type of bearing has been applied to the vertical type of hydraulic turbine, but it is believed to be safe to say that a rubber bearing will have a much longer life under adverse conditions than a lignum-vitae one.

Confident in the results so far obtained with the experimental bearing in the 1000-hp. turbine, a spare bearing for the 16,500-hp. single-runner turbine was lined with rubber, to replace the present lignum-vitae bearing, and was installed in the early part of December. This bearing is of massive proportions, having a bore of 24 in. and being 6 ft. long.[2] In this instance the bronze shaft sleeve or journal was not renewed, but it is recommended in similar

[2] Coincident with the modifications to this bearing, the turbine manufacturers advise they have under construction an 18,000-hp. vertical turbine in which a rubber-lined guide bearing will be placed.

installations that if the journal is worn eccentric that it be trued or replaced for the best results.

Although the merit of this type of bearing for large vertical units is yet to be determined, the author is confident it will be a marked improvement over past practice. Should these bearings prove successful, rubber will be substituted for lignum vitae in the double-runner turbines.

The cost of the rubber lining at present is much greater than one of lignum vitae, but the expected increase in life of the bearing and the less frequent renewals of shaft sleeves, should more than justify the increased cost.

THRUST BEARINGS

Roller Thrust Bearings. In the original design of the units provisions were made for roller thrust bearings, but they proved unsuccessful under the combined weight of the revolving parts and water thrust, which varies from 330,000 to 450,000 lb. This type of bearing was entirely abandoned after three years due to the rollers and tread plates or washers becoming badly chipped, making it necessary to replace them frequently with spare bearings at great inconvenience and considerable expense, as they were made of the highest grade of steel obtainable. These bearings operated very satisfactorily when new, but after several months of service began to show signs of distress. Bearings of this type were installed on large vertical units as early as 1905 at Niagara Falls and had given general satisfaction. A disk bearing of the water-pressure type was also tried out to replace the roller bearings, but was not satisfactory.

Kingsbury Thrust Bearings. The trouble with the roller bearings

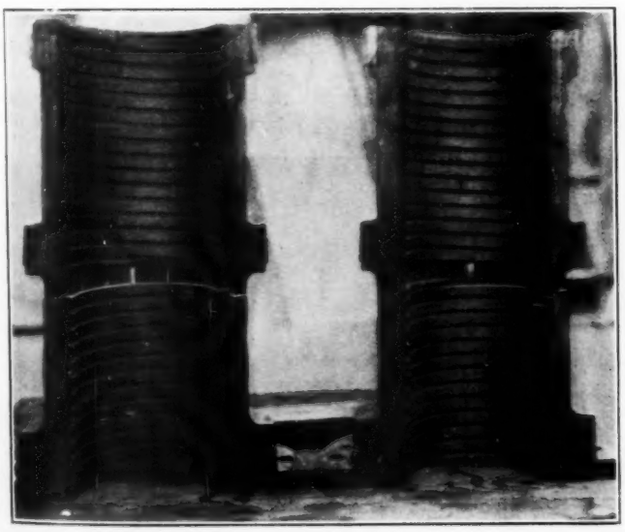

FIG. 5 EXPERIMENTAL RUBBER GUIDE BEARING FOR A 1000-HP. EXCITER TURBINE

became very acute during 1912, and during the early part of that year Mr. Albert Kingsbury requested a trial for the first application of his now well-known and successful type of thrust bearing for large-capacity vertical hydraulic units. After two years' satisfactory service with the Kingsbury bearing under observation, replacement of the roller bearings followed as quickly as opportunity permitted. These bearings to date have required no maintenance whatever. Inspections are made at five-year intervals, when two shoes are removed for observation and to take micrometer measurements of their babbitted faces.

The measurements taken of the No. 2 shoe of the first bearing, installed in June, 1912, showed that during the first three and one-half years the wear at point *b* was 0.002 in. and at *c* was 0.0025 in. (See Fig. 6.) After thirteen years' service the wear at point *b* was 0.005 in. and at *c* 0.0025 in. The points *b* and *c* are at the apex of the wedge-shaped oil film and are the points nearest the bearing runner when unit is running. The other two points *a* and *d* are at the entering of the oil wedge and indicate no wear whatever. Tool or scraper marks are still visible on parts of these shoes. Considering the maximum wear of 0.005 in. in thirteen years and allowing $^1/_8$ in. of wear on the shoes, would give, barring accidents and obsolescence of equipment, a life of 330 years.

The power loss in the 48-in. Kingsbury bearings varies from 9 to 12 hp., whereas the losses in the roller bearings were from 17 to 32 hp., the difference in the latter being attributed to the uneven surfaces of the tread plates when chipping developed.

MAINTENANCE OF GOVERNORS

All governors are of the double floating-lever type and require very little maintenance. Ample and constant lubrication of the various pin and bearing connections reduces wear and replacements to a minimum.

The entire mechanism is dismantled and cleaned yearly, and replacements made if needed. Originally the governor regulating and pilot valves were made of a composition bronze, but due to the increase of governor control pressure from 150 to 275 lb. the sharp edges of the bronze rings on the valve body and edges of port holes in the bronze liner were quickly worn away by the high pressure-governor fluid.

Monel metal was substituted for bronze, with a consequent

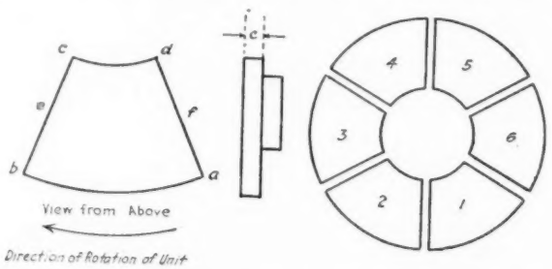

FIG. 6 NO. 2 SHOE FROM KINGSBURY THRUST BEARING OF NO. 5 UNIT

increase in the life of these valves from one year to four years.

Governor Gear Drive. The first five units were provided with belt drives, which were a constant source of trouble.

A gear drive through a horizontal shaft in which was placed a flexible coupling to dampen the vibrations from the gearing was substituted for the belt drive. Considerable experimenting was necessary to develop the flexible coupling now in use which enables the governor regulating valve to function properly. The desired cushioning effect is obtained by a set of four steel compression springs within the coupling, which are replaced about every four years.

The governor gear drive has proved itself to be one of the most reliable parts of the turbine equipment, there having been no replacement of gears or bearings in the past twelve years. It is the opinion of the author that gear drives for governors, if made of the best materials and if care is taken during installation to obtain accurate alignment, will be more reliable and the cause of fewer troubles than belt drives.

FREQUENCY OF DOUBLE-RUNNER TURBINE REPAIRS

Fig. 7 shows the periods when general repairs were made to the operating mechanisms of the No. 4 turbine. The instance referred to is typical of all double-runner units, but also indicates the progressive rate at which improvements were incorporated from time to time to decrease the frequency of general repairs from every two years originally to what is expected to be every twelve years in the future. It is doubtful if any further increase in the length of these intervals can be obtained, as the enormous amount of grit in the water will have caused such wear as to require replacements. It will, however, be necessary to continue experimentation on metals to determine those best adapted for service in the wearing parts.

Time of Turbine Repairs. The Holtwood hydro plant is classed as a "run-of-river" plant developed to several times the minimum river flow; the deficient or low-flow season begins in August and varies comparatively little from year to year. Opportunity is taken of this period of flow to make whatever turbine repairs are needed.

When a complete overhauling of a turbine is determined upon it is usually scheduled for August and three weeks' time allowed,

working 9 hours daily, to complete the job. However, when there is an expected increase in the flow of the river, the job can be quickly rushed through and the unit returned to service without delay.

There has been no marked change in the cost of these general repairs, but the necessity of making them will be less frequent in the future, resulting in a decided reduction in the annual maintenance costs per unit.

Maintenance of Single-Runner Turbines. The first single-runner unit (No. 8, 16,500 hp.) has been in almost continuous service since January, 1915, and has required practically no replacement of wearing parts to date with the exception of the renewal of the solid bronze sleeve on the turbine shaft. This sleeve is at the location of the lignum-vitae guide bearing where the silt contained in the river water caused the sleeve to wear eccentric and undersize. Minor repairs were made in the meantime, including the replacement of one operating-rod pin and bushing.

After eight years of service the vane shafts were worn 0.002 in. undersize, and the bushings enlarged 0.002 in. to 0.004 in.; steel

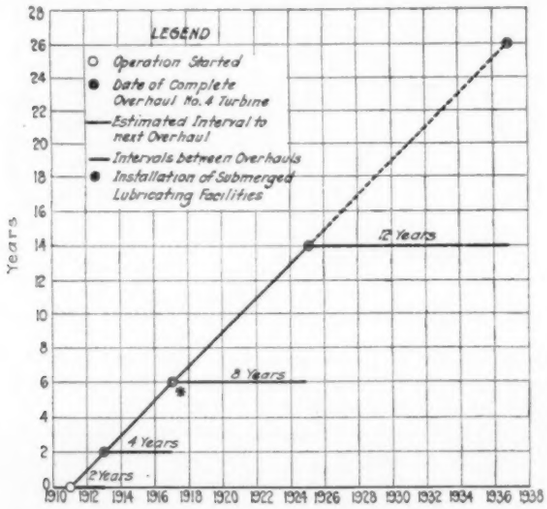

FIG. 7 MAINTENANCE CHART OF DOUBLE-RUNNER TURBINE

link pins, 0.002 in. to 0.004 in.; link bushings, 0.002 in. to 0.006 in.; operating-ring liners, 0.015 in.; radial liners, 0.012 in. The slight wear in this turbine may be attributed to good lubrication and to the small number of submerged wearing parts. From present indications there will not be any need of replacing the wearing parts in this turbine until 1930, or after fifteen years of service.

The last two units (Nos. 9 and 10) installed have been in service nearly two years, and it is expected that many years will elapse before renewals are necessary. There have been minor failures due to other causes than wear. For example, obstructions passing through vanes when the intake screens are raised during an actual run of frazil ice have caused the shearing of several of the cast-iron links in both turbines. Several failures of these links have occurred during normal operation, probably due to sudden changes in gate opening, and on examination, flaws were found in the castings at the predetermined point of shearing.

The maintenance of the wearing parts of the single-runner turbines is a comparatively simple problem compared to that of the double-runner machines, with a corresponding reduction in costs.

RELIABILITY OF HYDRO UNITS

Outages due to turbine or equipment failures rarely occur, and are as a rule only of several hours' duration.

The company's established practice of semi-annual turbine inspections and the replacements of wearing parts during the low-flow season permits of obtaining a "service demand availability factor" of nearly 100 per cent, this factor being the ratio of the time the unit is in service to the time the unit is needed in service. This high availability factor must be conceded to be largely dependent on stream flow, as in the case of a base-load station, it would be lower due to the "outage" time required to make necessary repairs to hydraulic equipment. The total "outage" time, or time the unit is not available for service, whether needed or not, because of inspection, cleaning, and repairs, is only about 5.2 per cent.

PITTING OF TURBINE RUNNERS

The pitting or corroding of hydraulic-turbine runners has in the past few years received considerable attention and thought from plant operators and turbine designers. The most generally accepted explanation of this trouble is that a high vacuum causes dissolved oxygen to separate from the water, with resulting corrosion of the adjacent metal walls. The excessive vacuum usually occurs at points where, for some reason, the water tends to pull away from the metal surface. This condition may be caused by excessive draft head (to which high specific speed may contribute), by poor design, by eddies caused by obstructions, or by part-gate operation. The pitted metal is honeycombed in structure and when the water is first drained out is bright and shiny in appearance, as the high velocities carry away the products of corrosion.

For many years Holtwood was free from trouble from this source. Turbines Nos. 1 to 5, in which pitting or cavitation is the most advanced, have been in service for from fourteen to fifteen years. During the first ten years the pitting progressed at a very slow rate, but apparently in the next four or five years it became greatly accelerated. In the double-runner units pitting occurs chiefly in the upper runners. In the single-runner units pitting is progressing very slowly, but slight evidences were first noticed after less than one year of operation.

Fig. 8 shows the nature and extent of a typical pitted area. Since repairs are made without removing the runner, it is difficult to obtain a clear photograph as the pitting occurs in constricted spaces.

Fig. 9 is a sketch indicating the affected areas on the buckets of the upper runner of No. 5 unit, which at the time of repair had

FIG. 8 NATURE AND EXTENT OF A TYPICAL PITTED AREA ON RUNNER

lost a greater amount of metal than any of the other runners; it may be taken as typical of the upper runners of units Nos. 1 to 4 also. Most of the buckets were pitted at four separate and well-defined areas which are located in the same relative positions on every bucket as follows:

I In the fillet at the top of the rim
II At curve of bucket on a line with the bottom edge of guide vane
III On bottom of bucket, running parallel to and about 6 in. from fillet
IV On bottom of bucket in fillet.

Of the four pitted sections, No. 1 was the deepest, being 2 in. deep on several of the buckets. The average lateral dimensions

were $3^1/_2$ in. by $4^1/_2$ in. About half of the buckets had small holes extending all the way through at area II. The areas marked III were the most extensive, the largest of these being 23 in. by $4^1/_2$ in.; the depths here, however, averaged less than $^3/_4$ in. The volume of pitted sections or voids was estimated by multiplying the product of the three dimensions by 0.75 to allow for the taper and irregular contour of the holes. The total volume for the upper runner of No. 5 unit estimated in this way was 1026 cu. in.

It is believed that the pitting of the two upper areas, Nos. I and II, is caused by prolonged operation during low flow at part-gate opening, when the jets of water impinge on the runner buckets at an angle, causing eddies back of the edges of the buckets. On the other hand, that of the lower areas, Nos. III and IV, is probably caused by excessive draft head during low flow, when the tailwater is low. This theory is borne out by the fact that areas I and II appear on both the upper and lower runners, although they are much less advanced on the latter, whereas areas III and IV occur only on the upper runner. The lower runner is set so low that it cannot be subjected to excessive draft head.

Method of Repair. Repair by the electric-welding process before the pitting or cavitation has reached an advanced stage appears at present to be the only effective method of replacing the metal on the affected portions of the runner. The runner is left in place during the work.

Since the company had had no experience in electric welding, repairs to the first runner were made by an outside contracting firm which had done a considerable amount of this class of work. The company then purchased two portable single arc-welding sets and has welded the upper runners of two units—No. 4 last year and No. 5 this year—with its own maintenance men.

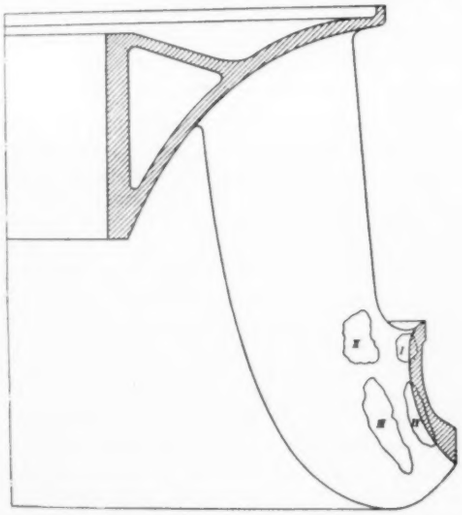

FIG. 9 AFFECTED AREAS ON BUCKETS OF UPPER RUNNER OF NO. 5 UNIT

The first operation of the actual repair work, after suitable platforms are erected around and below the runner, is to chip out the rough surface of the pitted areas with small air chippers. The chipped surfaces are then drilled and tapped for $^1/_2$-in. steel studs, which are spaced on 2-in. centers and project $^1/_2$ in. above the chipped surface. These studs serve as anchors for the welding metal, and are necessary when welding cast iron, as the properties of the latter are such that the union between the cast iron and welding metal is of a doubtful nature. Fig. 10 shows a bucket after the chipping and studding has been completed and the bucket is ready for welding.

Two welding sets are used, each of one electrode capacity. First a priming layer of low-carbon steel is applied, after which the remainder of the weld is finished by using a higher-carbon steel which has better water-resistant properties than the priming metal. As the welding progresses, each layer of metal deposited is peened with an air hammer to relieve internal stresses.

The surfaces of the welded areas on completion of the weld are usually rough and do not conform exactly to the contours of the buckets. These surfaces are smoothed and correctly shaped by special portable grinders.

The considerable expense involved in these repairs suggested trying out the merits of Smooth-On, litharge, and cement in the cavitations in the first runner welded, but these experiments were unsuccessful. Type metal was also tried in several places, and after one year's service was found in its original condition. The method of filling the cavitations was to form a mold to fit the curvature of the bucket, into which the molten metal was poured from a ladle; after the metal solidified it was thoroughly peened to relieve stresses. The cavities were neither chipped nor studded, but filled "as found."

Should this method of repair prove successful it will be much more easily and quickly done, and the cost will be but a fraction of that of the electric-welding process.

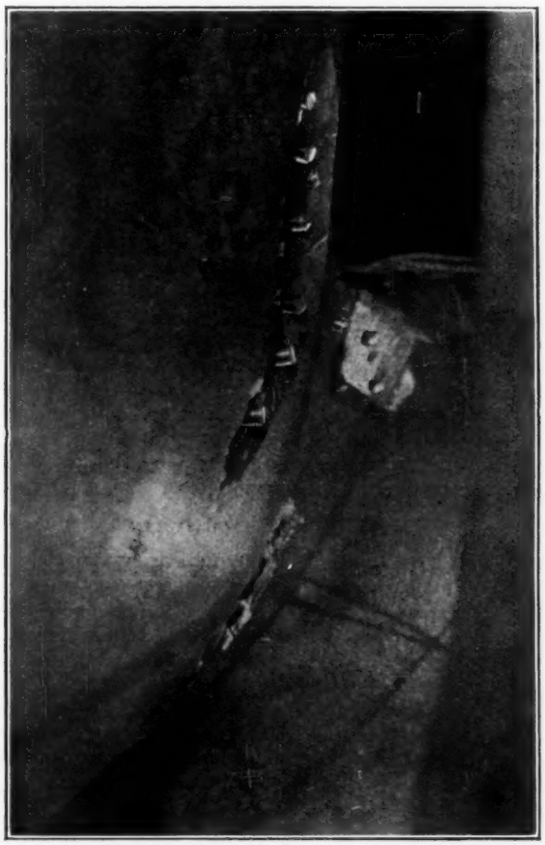

FIG. 10 BUCKET AFTER CHIPPING AND STUDDING

Cost of Welding. The following tabulation shows the cost and time required to weld the upper runner of unit No. 4 in 1924 and of No. 5 in 1925. The decrease in cost, and particularly in welding hours per pound of metal due to the growing experience and skill of the company's men, is very marked. The costs include the expense of preparing the wheel pit, erecting scaffolds, and all other incidental costs. No part of the first cost of the welding sets themselves is included.

	Unit No. 4	Unit No. 5
Total cost of job	$2,919.25	$2,439.20
Estimated volume of pitting, cu. in	979	1026
Welding metal used, lb	505	596
Metal actually deposited, lb	354	417
Time required for welding, hr	1274	821
Cost per lb. of metal used, based on total cost of job	$5.78	$4.10
Cost per pound of metal actually deposited on each runner, based on the total cost of the job	$8.27	$5.85

From this tabulation it will be noted that the cost per pound of metal deposited on No. 5 is only 71 per cent of the cost on No. 4.

SAFE PRACTICES DURING TURBINE REPAIRS

Steaming of Wheel Pits. It may be of interest to mention here that when a turbine is taken out of service for extensive repairs,

the wheel pit or scroll case is pumped dry and high-pressure steam is forced into same for a period of two hours. The high-temperature steam kills all germs and bacteria and dries all the metallic parts and concrete walls. Before this precaution was adopted the slightest cut or skin abrasion received by workmen when engaged on turbine work developed into a painful sore.

After the steaming of pit is completed, the four headgates are opened and fresh air admitted. The opening of these gates is made possible by placing emergency gates in slots 6 ft. ahead of the intake gates. Fresh air is forced into the wheel pit through two 3-in. conduits from a blower located on the gate-house floor, as the air in the pit becomes very humid and stale without forced ventilation.

Electric-Shock Hazard. Special low-voltage equipment is used for the illumination of all turbine work or work of a temporary nature in any other parts of the station below the forebay or tailrace levels. Standard 220- or 110-volt lighting has been found very dangerous on account of shocks from grounded lighting cords and fittings due to the generally wet conditions under which this class of work is done. A special 5-kw. transformer is used for this purpose. It is connected to the station 220-volt a.c. lighting bus and steps down to 32 volts, which is safe and involves no hazards whatever. Standard 32-volt lamps and fittings are used so as to prevent the accidental use of this equipment on 220-volt fittings. These fittings are now being abandoned and standard fittings substituted having left-hand instead of right-hand threads; this includes sockets, attachment plugs, and lamps.

It is the opinion of the author that 32-volt lighting equipment should be more generally adopted by all industries having similar below-water-level work or any other wet or damp surroundings so as to entirely preclude the possibility of fatal or severe shocks, and possible falls from scaffolding caused by shocks. Fatalities or severe shocks are not uncommon from 220 volts potential.

Governor Control System

The original governor control or pumping system consisted of five 50-hp. turbines, each driving a six-stage centrifugal pump at 150 lb. operating pressure, there being one set for each of the first five units installed. The governor fluid was raw river water drawn directly from the forebay, regardless of its condition. As previously explained, the corrosive effects of the water in a few months caused considerable friction to develop in the operating mechanism, necessitating increasing the governor control pressure to such an extent that the original pumping equipment was inadequate.

During 1912 a central pumping system was installed, the general scheme of which is common main and auxiliary pressure and exhaust headers to which the governing equipment for every unit is connected. The pumping equipment consists of five large high-pressure motor-driven six-stage centrifugal pumps connected to pressure headers and operating at 275 lb. pressure.

Method of Treating River Water. When this system was installed no provisions were made for combating the corrosive effects of the river water; the piping, valves, accumulators, and sump tanks being made of extra heavy steel but not galvanized.

It would be a long story to relate the many difficulties experienced both in operation and maintenance in overcoming the solvent and attending troublesome sludges which formed within the system by using river water with various chemical admixtures to prevent corrosion. The present method is to use barium hydrate as the neutralizing agent. The water is treated in a mixing tank external to the governor system. A concrete tank on the stop-log gallery having a capacity of 30,000 gal. was made use of for this purpose. Only filtered river water is now used. The method used to prepare the fluid for the system is as follows:

The tank is filled to a certain height with filtered river water from the filtration plant, and 1 lb. of barium hydrate is put in the tank for every 250 gal. of water. The treated water is allowed to stand for at least 80 hours, in order to precipitate the barium sulphate and barium carbonate. It is necessary to have a film of oil about $^1/_{16}$ in. in thickness to cover the surface of the water in the tank to prevent the carbon dioxide in the air from affecting the barium hydrate. The clear fluid is then drawn from 2 ft. from the bottom of the tank by an ejector into one of the sump tanks in the central pumping system.

The fluid when admitted into the system from the mixing tank is in a rather concentrated form, but if left in the system for a period of over a week without admitting a fresh supply it will revert to its former state and the sulphuric acid radicals will appear again, due to the excess of barium hydrate being used up by carbon dioxide in the air. The slight amount of leakage in the system is daily replenished from the mixing tank, which is sufficient to more than satisfy the solvent action of the water with its dissolved oxygen.

Under the present method of treating the water with barium hydrate, corrosion in the various parts of the system has been reduced to a negligible degree and the method is giving excellent results.

Governor-Control Pumps. The six-stage pumps have proved very reliable equipment and required few repairs. One of the largest pumps, having a capacity of 900 gal. per min. at 300 lb. pressure and driven by a 300-hp. motor, has had its first overhauling this year after a period of 13 years of continuous service. These repairs consisted of the replacing of the first- and sixth-stage impellers, the hydraulic thrust disk, and the bronze bushings on the shaft at the location of the low- and high-pressure stuffing boxes. The other four pumps will not require overhauling for at least five years.

Pressure Headers. Despite the lack of any protection against corrosion in the various governor pressure headers and piping, there have been few replacements, whereas all other pipes, galvanized or ungalvanized, carrying river water have a comparatively short life and must be replaced occasionally. Originally the internal working parts of all valves were cast iron, and corrosion was responsible for considerable trouble with these parts. Bronze gates, toggles, and yokes have been substituted. For all extensions and new installations, galvanized piping, valves, and fittings have been adopted as standard.

Inspections

Every possible endeavor is made to maintain the entire station equipment in first-class operating condition at all times. This is made possible by a very thorough system of inspections. A complete set of maintenance and inspection instructions have been issued, detailing how apparatus is to be inspected, what is to be looked for, and what precautions are to be observed.

Assignment of Inspections. The work of making the hydraulic inspections is assigned partly to the hydraulic operating attendants and partly to the mechanical inspector. While the operating men make the majority of the routine inspections, it is necessary that some of the apparatus shall have a more thorough inspection, which is made by the mechanical inspector.

A system of white printed charts has been developed on which is provided a place for every item of equipment to be inspected. The charts show clearly to whom the inspection is assigned, indicate whether the inspections are to be made monthly, quarterly, semi-annually or annually, and provide a place for recording the date of the inspection and the initials of the man who made it. These charts are posted on a display fixture readily accessible to the men who are making the inspections, so that their progress is continually in view. Following are features of the hydraulic inspection charts in use.

Progress Chart of Hydraulic Inspections. This chart refers to the periodic hydraulic inspections made by the hydraulic operating floormen and the mechanical inspector, covering all of the hydraulic and mechanical equipment excepting turbines. All inspections must be briefly covered by a written report, after which entries are made on the chart. All inspection charts have been worked out on the assumption that when a piece of machinery is inspected it is found to be either right or wrong. If it is right, the entry is made and if it is wrong, the letter "T" accompanies the entry and a trouble-report form is made out. If it is discovered that deviation from normal has taken place, the trouble is corrected.

Turbine-Inspection Reports. The situation with regard to hydraulic turbines is somewhat different, as they involve separately a large number of operating and wearing parts. In such cases it is difficult to form a comprehensive picture of the condition of all the various details of the units.

Turbine-inspection reports, of which there is one for each turbine,

have now become permanent records. In the left-hand column of the chart is listed each of the seventy-odd turbine parts which it is desired to check up. Note is made of the material of which each part is made. The instructions for turbine inspection call for numerous detailed measurements of lost motion, clearances and wear, and for observation of the general condition of each of these parts. The inspections are made semi-annually and are recorded in successive columns on the charts. The enumeration of these various measurements and observations prevents their being forgotten. Instead of conditions being reported in vague general terms, specific measurements are called for.

These charts have been an important contributing factor in cutting down the labor required in overhauling a turbine from twenty to thirty men for thirty to forty days once every three years to a matter of about ten men for twenty days once in six or seven years.

Trouble Reports. Reference has been made to the filling out of a trouble report in case an inspection shows that the apparatus is not in its normal condition. This trouble report becomes authority and instruction for the maintenance force to repair the equipment and restore it to its normal condition. When the job has been completed, record is made on the report of what caused the trouble, how it was corrected, what was done or what should be done to correct similar defects in the future, and any other details about the repair which might be of permanent interest.

These reports play an important part in the company's preventive maintenance, for the reason that by them it is possible to keep a watch on the effectiveness of the station inspection and maintenance procedure.

Problems of the Wood Industries

Information on the Strength of Boxes, Motor-Driven Molders, High-Speed Induction Motors and Frequency Changers, Glue Testing and Grading, and the Prevention of Forest Fires Arising from Locomotive Sparks, Brought Out in Discussions at the 1925 A.S.M.E. Annual Meeting

AT THE Annual Meeting of the A.S.M.E. held in December last, several papers of importance were presented at a session held under the auspices of the Wood Industries Division of the Society, Thomas D. Perry[1] presiding. These papers dealt respectively with scientifically developed boxes, crates, barrels, and other shipping containers, motor-driven molders, glue evaluation, the application of high-speed induction motors and frequency changers to woodworking machinery, and with the prevention of forest fires arising from locomotive sparks. A summary of the discussion brought out by these papers is given below.

Scientifically Developed Shipping Containers[2]

C. M. BONNELL, JR.,[3] presented a paper under the above title in which he dealt with the yearly cost of packing and shipping commodities; the standardization of lumber for containers, wooden boxes, crates, casks, and barrels; tests on containers; and on loading and bracing containers in cars.

ENERGY CONSIDERATIONS IN THE FALL OF BOXES

In a written discussion which he submitted, J. R. Watkins[4] said that an inquiry into the strength of boxes must necessarily lead to a careful analysis of the exact causes of the failures. When a box fell it acquired a considerable amount of kinetic energy, depending on the height of fall. The energy was dissipated in the form of heat when the box struck the ground, with a small rise in temperature in all parts in which the energy was absorbed. It was of course wrong to assume that at the instant contact was made the box came to rest, for under these circumstances the kinetic energy could not be consumed. At the first contact of the box with the floor or ground the reaction was initially small, but quickly mounted as the box stiffened, and soon became many times as great as the weight of the box itself. If the box were entirely inelastic there would be no rebound, but as a rule, most of the energy was absorbed elastically through internal friction. That part which was absorbed elastically functioned as the energy in a compressed spring and caused the box to rebound. After rebounding the box fell again and then the absorption of the energy through internal friction was usually completed. Energy absorbed internally through friction disappeared as heat, either in the contents or in the sides and joints of the box itself. The ideal box would be one in which all the energy would be absorbed by the box and none by the contents. Such a condition could of course be obtained only partially in practice, but it was the end which rational box design attempted to reach. The corrugated-fiber shipping container, for example, was an improvement over many types because the padding afforded by the corrugations functioned as a shock absorber. In most wood boxes and largely in the wirebound container that part of the energy of a fall not absorbed by the contents was consumed in part by the friction between boards where they were nailed together. It was also partly consumed by the twisting or bending action of the boards, by pulling of nails, or by crushing of the wood under the nail heads. Some of the energy might be consumed in denting the floor or in setting up vibrations, or a corner might be crushed, or a wire might be stretched. If the contents permitted distortion, then much more of the energy could be consumed by the box itself, but this was forbidden on account of possible injury to the contents resulting from a change in shape. Each distortion loosened the nails in the wood box, and the effect of repeated falls was cumulative, so that the ends of the boards would soon split and the box go to pieces.

INFLUENCE OF MOISTURE ON THE STRENGTH OF BOXES

It might be rightly assumed, wrote Mr. Watkins, that the nailed joint was the weakest part of the average box. The principal factors which influenced nail-holding power were change in moisture content of the lumber, density of the lumber, and size of nails. The moisture content of the different species of woods when green might vary from 30 per cent to 200 per cent. Generally speaking, those of high specific gravity contained less moisture than those of low specific gravity because there was less room in the dense woods for the free moisture. However, all woods began to shrink at about the same moisture content, as determined by a study of nearly all the commercial woods. All moisture over approximately 27 per cent was free moisture, and the physical and mechanical properties, except those in "impact bending," were not affected until the wood had been dried to the point which was known as the "fiber saturation point." When the drying continued below the fiber saturation point a noticeable increase in the mechanical properties except those in "impact bending" took place. Wood shrank in a straight line from the fiber saturation point to the "bone dry" condition. The curves in Fig. 1 had been compiled by Mr. Watkins from measurements on 1-in. × 1-in. × 4-in. pieces of Douglas fir. The fiber saturation point was determined by the intersection of the tangents. It would also be noticed that shrinkage in the circumference was greater than shrinkage radially. Woods of high density shrank more than those of low density.

When a nail was driven into a piece of green wood and the wood dried, there was shrinking at the nail with a resultant loss of friction and nail-holding power as shown in Fig. 2. The shrinkage of wood was greater tangentially and radially than longitudinally, and as a result there was effective friction on two sides of the nail only,

[1] Past-Chairman, Wood Industries Division. Comstock Park, Mich. Mem. A.S.M.E.

[2] Published in the Mid-November, 1925, issue of MECHANICAL ENGINEERING, p. 979.

[3] Engineer, Freight Container Bureau, New York, N. Y. Jun. A.S.M.E.

[4] Chicago Mill & Lumber Co., Chicago, Ill.

after drying took place. Wood shrank about 0.02 of 1 per cent longitudinally or in the direction of the fiber length.

The chart in Fig. 1 of the paper showed boxes tested at 15 per cent as 100, whereas those at 30 per cent were 90, with both tested immediately after being nailed. This difference might be the result of the increase in modulus of elasticity of the dry wood over the green. Tests had shown that the modulus of elasticity for air-dry wood was 3,000,000 G and that of green wood 2,500,000 G, where G was the specific gravity. The boxes nailed and tested at 5 per

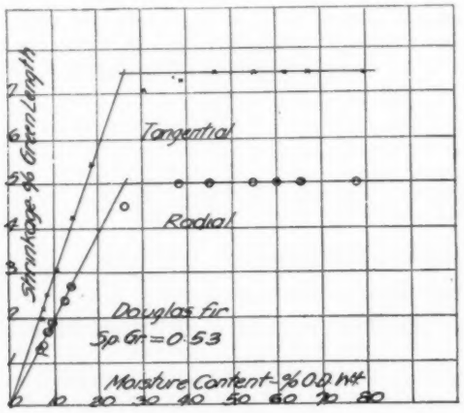

FIG. 1 SHRINKAGE OF DOUGLAS FIR FOR VARIOUS MOISTURE CONTENTS

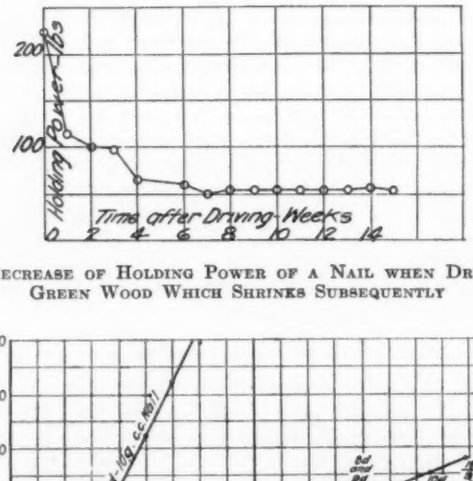

FIG. 2 DECREASE OF HOLDING POWER OF A NAIL WHEN DRIVEN INTO GREEN WOOD WHICH SHRINKS SUBSEQUENTLY

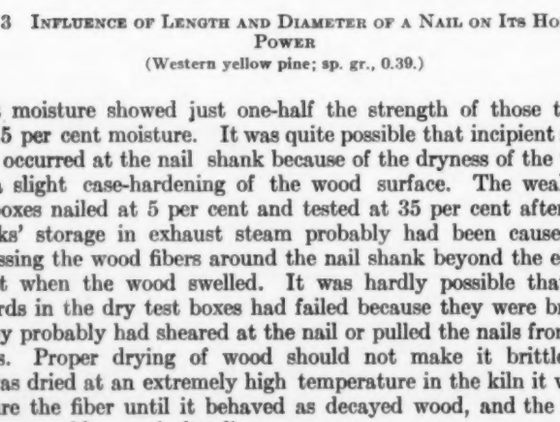

FIG. 3 INFLUENCE OF LENGTH AND DIAMETER OF A NAIL ON ITS HOLDING POWER
(Western yellow pine; sp. gr., 0.39.)

cent moisture showed just one-half the strength of those tested at 15 per cent moisture. It was quite possible that incipient splits had occurred at the nail shank because of the dryness of the wood or a slight case-hardening of the wood surface. The weakness in boxes nailed at 5 per cent and tested at 35 per cent after two weeks' storage in exhaust steam probably had been caused by stressing the wood fibers around the nail shank beyond the elastic limit when the wood swelled. It was hardly possible that the boards in the dry test boxes had failed because they were brittle. They probably had sheared at the nail or pulled the nails from the ends. Proper drying of wood should not make it brittle. If it was dried at an extremely high temperature in the kiln it would injure the fiber until it behaved as decayed wood, and the crash failure would occur in bending.

RELATION OF WOOD DENSITY TO NAIL-HOLDING POWER

With a constant moisture content, wrote Mr. Watkins, the holding power of a nail depended upon the density of the wood, and for practical use it might be assumed to be a straight-line relation. All wood substance was practically of the same weight, and the weight of a piece of dry wood when free of resinous material was an indication of the amount of wood substance it contained. It was evident that the more wood substance there was in a given species, the greater its strength and nail-holding power were likely to be. A nail driven into dense wood produced greater splitting force than when driven into lighter wood, but the dense wood had a

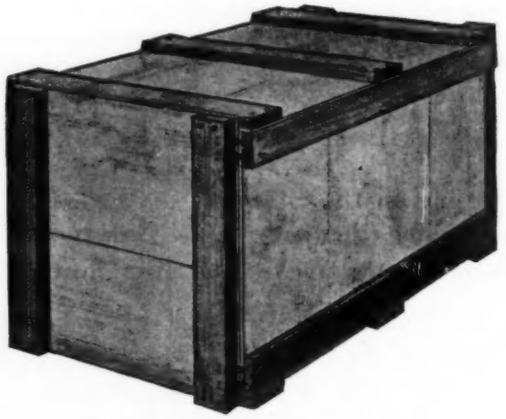

FIG. 4 HINGE-CORNER CRATE

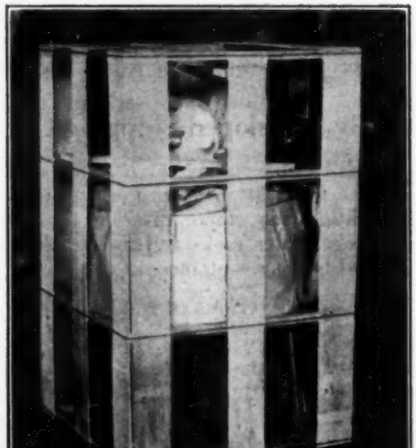

FIG. 5 WIREBOUND CRATE

greater resistance to splitting than the light wood, so that the two factors tended to counterbalance each other but did not do so entirely.

Another factor which influenced the resistance of wood to splitting was the interlocked grain.

The grouping of woods as determined at the Forest Products Laboratory and given in the paper was convenient for reference, and a nailing schedule to be used with it had also been prepared by the Laboratory.

RULE FOR DETERMINING NUMBER AND SIZE OF NAILS

A rough rule for practical purposes was as follows: In using the slender or box nail in species of medium hardness, the "penny" of the nail should not be greater than the thickness in eighths of an inch of the wood which held the point of the nail. For softer woods, nails might be one "penny" larger. For the hardwoods one "penny" smaller should be used.

When nails were 6 "penny" or less, those holding boards to the end grain of end should be spaced 1¾ in. apart, and those holding

boards to the side grain of end, 2 in. apart. Spacing of nails should be increased 1/4 in. for each penny over 6. No board should have less than two nails.

The holding power of a nail varied directly as the length and directly as the diameter. Fig. 3 showed results of direct pull on the head of the nail. The load had been slowly applied by an Olsen testing machine.

STRAPPING BOXES

Tests on about 2000 nailed boxes made at the Forest Products Laboratory showed that the thickness of lumber in the sides, top, and bottom of boxes could be materially reduced when properly strapped. The following table had been compiled from the tests.

Thickness of S. T. & B. unstrapped boxes, in.	Thickness of S. T. & B. of strapped boxes, in. One strap	Two straps
7/8	5/8	1/2
13/16	5/8	1/2
5/8	1/2	3/8
9/16	7/16	5/16
1/2	3/8	5/16
7/16	5/16	1/4
3/8	5/16	1/4

HINGE-CORNER, WIREBOUND, AND PLYWOOD BOXES—INTERIOR PACKING

Hinge-corner, wirebound (Figs. 4 and 5), and plywood boxes were often found better suited than the nailed box for shipping commodities. Briefly, the chief advantage of the first two was the small amount of storage room required, and the fact that they were delivered about 80 per cent assembled.

The hinge-corner crate was being used extensively for shipping gas ranges and washing machines.

The plywood box was the most rigid box of all. It would take a 6000-lb. load diagonally applied to the corners at a compression of 1 1/2 in. When waterproof glue was used in the manufacture of the plywood, the box was proof against the elements.

The interior packing was probably more important than the container, and a more detailed study of damaged shipments by the railroads would show this to be true.

In the oral discussion D. S. Hartshorn[5] referred to the possibility of standardizing boxes, manufacturers agreeing to a certain standard light package, collecting it, and using it over and over again. The author stated that in a few instances this had been done. In one case he knew of, the canning factory shipped empty cans from the manufacturer's plant to the filling plant and used that package to bring another shipment to the filling plant. Mr. Watkins said that the American Canning Company had a type of returnable package that could be sent to the can user and then back to the factory again, probably for about twenty-five trips. As to the use of a nailed wooden container over again, he thought that shipping from one point to another would impose too great a stress on the nails. Without cutting off the ends of the boards that held the nails, there would be considerable breakage on the contents of the box because of the loosening of the nails and of the nail shank.

P. A. Dahill[6] pointed out that sixty per cent of the wooden containers were second-hand containers, or were used over again. A second-hand container was separated from those which were obviously worn out. A container which had been nailed together and had been reused over two or three times had ten times as much probability of failing and allowing its contents to be damaged as a similar container in new condition. As to the matter of return of boxes obviously built for reuse, there was a question of economics to take up in regard to the return freight rates. Manufacturers found that the biggest difficulty was that their customers did not return the boxes to them. A box they would ordinarily use once cost about 28 cents. For a return container they had to pay from $2.50 to $2.75. Receivers of such special containers found them useful and did not return them, and the manufacturers found it difficult to impose a penalty for non-return, because that would result in loss of orders.

[5] Darling Valve Mfg. Co., Williamsport, Pa. Mem. A.S.M.E.
[6] Chief Engineer, Freight Container Bureau, New York City.

The Electric Molder[7]

IN A PAPER bearing this title, Andrew Jensen, Jr.,[8] analyzed the power requirements of the motor-driven molder and its production possibilities in woodworking, and compared it with the belt-driven molder.

In the oral discussion following its presentation, Chairman Perry asked whether the electric-driven molder was capable of such speeds as to give a smooth cut, or was there an advantage in the even higher speeds attainable by the air-driven molders that were being used so much for routing machines and boring operations. D. S. Hartshorn[9] pointed out that lathe manufacturers had changed their gear head to a belt-driven machine in metal working to get a smooth cut and inquired whether any difficulties had been found in regard to the cuts given by either the belt machine or the electrically driven machine. Mathew Lund[10] wished to know if the author had found any difficulty in balancing heads on account of magnetic unbalance in the molders. Mr. Lund had himself experienced considerable difficulty with high-speed induction molders on account of magnetic unbalance. That there was magnetic unbalance had been determined by careful examination of the solid cutters and the ball bearings and spindles. He thought there might have been a possibility of the critical speeds of the shafts having been reached. The effect was that in highly finished work such as carving and fine molding the work was marked in a manner which could not be passed. W. A. Furst[11] had also had experience with magnetic unbalance. This was due partly to the number of slots and the state of the winding, and partly to the size of the shaft employed. With a shaft of fairly small diameter, the molder gave a sort of impulse and started a vibration, due to the number of the slots, and this vibration continued even after the molder was up to full speed, the shaft not being heavy enough to overcome this vibration. A different combination of rotor slots would remove this vibration even with the light shaft. In regard to the use of belts in molders, Mr. Furst had found that when hardwood with some knots in it was being used and the cutter was working on the knots, the belt tended to slip and a number of knife marks resulted.

The author answered each speaker in turn during the discussion. In replying to the chairman's question, he stated that 3600 r.p.m. gave a very satisfactory finish up to 100 ft. per min. lineal cutting speed, but beyond this speed up to 150 ft. per min. or more, it was advisable to have a higher r.p.m. of the cutter head. This was being obtained by the use of frequency changers since the higher molder speeds were absolutely unattainable in the belt-driven machine. Answering Mr. Hartshorn's query regarding difficulties in getting smooth cuts, he said that with the electric molder it was necessary to line up the bearings, which required care, but this had been done successfully and the cuts obtained with the electric molder were as satisfactory as those obtained with the belt-driven machines. Answering Mr. Lund, he said that he had not encountered the difficulty of magnetic unbalance, but agreed that the question of critical speed of shafts should be looked into.

Recent Advances in Methods of Glue Evaluation[12]

IN THIS paper Wilbur L. Jones[13] discussed the various difficulties presented by the problem of glue testing, viscosity and jelly-strength tests, and standard methods of conducting such tests.

J. R. Powell,[14] in discussing viscosity tests, wrote that the author had spoken of the effect of agitation on the viscosity. It was generally held that the effect of agitation was to reduce the viscosity. However, recent yet unpublished work had tended to discredit this belief. Apparently at the temperature at which the

[7] Published in the Mid-November, 1925, issue of MECHANICAL ENGINEERING, p. 984.
[8] Bigelow, Kent, Willard & Co., Inc., Consulting Engineers and Accountants, Boston, Mass.
[9] Darlington Valve Mfg. Co., Williamsport, Pa.
[10] Grand Rapids, Mich.
[11] Westinghouse Elec. & Mfg. Co., Pittsburgh, Pa.
[12] Published in the Mid-November, 1925 issue of MECHANICAL ENGINEERING, p. 1072.
[13] Analytical and Consulting Chemist, Madison, Wis.
[14] Chief Chemist, Armour Glue Works, Chicago, Ill.

viscosity was determined (60 deg. cent.) the solution was truly viscous, and mechanical agitation had no influence upon it. However, glue was a product of the hydrolysis of nitrogenous animal substance by heat in the presence of water, and continued heating tended to carry this hydrolysis on farther, with a corresponding reduction in viscosity. Although this change was not rapid, undue exposure, or the exposure of different samples to heat for varying lengths of time, should be avoided.

Under the discussion of the jelly-strength determination, the author had called attention to the necessity of exact temperature control of the chill bath in which the samples were prepared for the jelly test. This was of very great importance and could not be emphasized too strongly. It might be of interest to know that a suitable chill bath was now obtainable which operated within the required limits. The Sarco Co., Inc., had built a number of baths of this latest design that had been entirely satisfactory in practical use.

With reference to the Glue Association grades, Mr. Powell wrote that it was possible that a little history on the selection of these grades would offer an explanation as to why the jell and viscosity grades frequently did not coincide. In the first place, even if they did coincide for average glues, there would still be a great many glues whose jell and viscosity ratios differed from the average and so would not even then give the same jell and viscosity grades. So that to describe a glue definitely, it was necessary to give both its jell and viscosity tests, there being no fixed relation between these. Next the grades both for jell and viscosity had been arrived at by first determining the manner in which these tests had varied upon blending glues of different grades and then so arranging the grades both for jell and viscosity that the glues would blend according to grade. That was, if equal parts of grade 8 were mixed with equal parts of grade 12, the resulting mixture would give the test of grade 10. If one-quarter part of grade 12 was mixed with three-quarters part of grade 8, the test of the resulting mixture would be that of grade 9. This applied to either the jell or viscosity grades. Now it had been found by experiment that when blending glues the viscosity grade did not vary at the same rate as the jell grade. That was, when the results had been plotted, the viscosity curve had had more of a dip in it than the jelly curve.

With this in mind, it was perfectly obvious that the two sets of grades could not be made to coincide over the entire scale. As a result, when using the average ratio of jell to viscosity the Association grades did approximately coincide at the lower and upper end of the scale, but the viscosity grade would run about two numbers above the jell grade in the center of the scale. It being impossible to establish a set of grades worked out upon the properties of glue that would coincide, it had been deemed advisable to adopt grades that were so selected rather than adopt arbitrary grades that on the average could coincide, but which did not depend upon any property of the glue itself. This caused no great inconvenience in practice. For the Glue Association uses it had been decided to speak of a glue by designating both grades, giving the jell grade first; that was, an 8–10 glue would be one showing an 8 jell grade and a 10 viscosity grade.

In the oral discussion which followed, P. H. Bilhuber,[15] who had read the paper in the absence of the author, replied to many questions raised by discussions.

J. R. Watkins asked whether the viscosity test could be applied to casein, vegetable, and blood-albumen glues as a means of determining their strength. His company had just started manufacturing a plywood package. They liked to glue it up direct from the veneer without first drying the water out of the wood. For furniture purposes Mr. Watkins said that it was best to dry the wood down to possibly 2 or 3 per cent moisture content, because by the time the glue was added to it, there was a sufficient amount of water in the glue to raise the moisture content of the wood back to room condition, say, 8 per cent. He wished to know how much the veneer should be dried in order that the casein glue might be expected to stick reasonably well.

Chairman Perry referred to a Russian process of dealing with green veneer. In this process a film or thin sheet of blood-albumen glue was placed against the green veneer, and the two were put in a hot press. The expense of the process had militated against its adoption. H. H. Suplee[16] stated that he was very familiar with the Russian blood-albumen process. He stated that it was absolutely a coagulation process, the blood albumen hardly adhering at all without heat. The platens of the press were heated by steam at a pressure of 30 to 40 lb. per sq. in. The presses were usually made with a number of platens, for reasons of economy, since large quantities could thereby be handled at one time. The glue was spread cold upon the veneer, which could be absolutely raw. The moisture all dried out in the press, and the veneer was absolutely perfect in twenty minutes. The pressures in the press ran to as much as 100 to 200 lb. The veneer thus prepared with blood albumen was waterproof; the albumen, after it had been boiled in the press, could be treated or soaked in any fashion, but would never redissolve. Gelatin glues, on the other hand, were reversible and would redissolve when soaked. The blood-albumen process could be applied with platens of special form to such articles as barrel hoops, angles for trunks, and special beam forms for airplanes.

Mr. Bilhuber pointed out that the viscosity test could not be taken alone as determining the glue. In regard to viscosity tests for casein glue, he said that glue of this nature was too viscous to flow out of a pipette such as was used for determining the viscosity of animal glue, but with a larger-sized pipette satisfactory tests could be made. Vegetable glue was hard and sticky, and would not flow from a pipette of any size. With regard to the drying of veneer before gluing, he mentioned that a very large plant in the Middle West made panels taking the veneer at about 15 to 20 per cent moisture. Some cabinet shops, on the other hand, did not apply casein glue until the veneer was bone dry, with a moisture content of only 2 or 3 per cent. With regard to the waterproof qualities of casein glue, he stated that it was not absolutely waterproof but relatively so, and could be used for internal partitions. He also said that when a glued joint was soaked in water it was nearly always the wood that fractured, so that the glue was actually superior to the material joined. In regard to the waterproof qualities of gelatinous glues, he had made some interesting experiments with bichromate of potash, which became insoluble when exposed to light. The paper was strictly limited to animal glues, and Mr. Bilhuber thought it was unfortunate that with the newer glues such as casein and vegetable glues just coming into use, so little was known regarding the methods of testing them and also of the methods of control in manufacture.

Spark Arresters and Forest Fires

AT the conclusion of the foregoing discussion, J. S. Mathewson[17] presented a paper the text of which immediately follows.

In recent years engineers have become more and more interested in the conservation of our natural resources and doubtless recognize in a general way that fire prevention is indispensable not only in the case of standing timber but also in the growing of timber under a policy of reforestation.

The Forest Service, of course, is vitally concerned in postponing the "day of reckoning" which will surely come if due attention is not given to the conservation of our timber supplies both through protection and through efficient utilization. With the rate of consumption four times that of growth, it is obvious that the supply cannot last indefinitely.

With these facts in mind, let us review what has been done in recent years with respect to the prevention of forest fires caused by the escape of sparks from mechanical equipment and then may I suggest what might be undertaken as the next steps.

PAST INVESTIGATION

In 1920 and 1921 the Forest Products Laboratory made a study of front-end arrangements for common-carrier locomotives and logging locomotives, and spark arresters for donkey engines, portable sawmills, and tractors. Rather comprehensive information on the subject was obtained through correspondence and personal interview with members of the Forest Service, State foresters, conserva-

[15] Assistant Factory Manager, Steinway & Sons, Long Island City, N. Y. Assoc. A.S.M.E.

[16] New York, N. Y. Mem. A.S.M.E.

[17] Engineer in Forest Products, Forest Products Laboratory, Madison, Wisconsin. Mem. A.S.M.E.

tion commissions, railroad companies, lumber companies, and manufacturers of locomotives and spark arresters.

PRESENT NEED FOR RESEARCH

(*a*) At the time the study referred to in the preceding paragraph was made, a wide divergence of opinion concerning the relative merits of various fire-protective appliances on mechanical equipment was very evident. Subsequently, Forest officers and others have had an opportunity to give further attention to the subject and a correlation of present ideas is highly desirable. In any event, however, many questions are still unanswered and require actual tests of fire-protective appliances. It is in this connection that the Society's coöperation would be of great public benefit.

(*b*) Recent reports obtained by the Forest Service and covering a period of eight years indicate an average for that period of 41,500 fires annually, with 9,051,000 acres of forest land burned over, and an immediate property loss of $17,885,000. These losses, chiefly to timber and improvements, probably represent the smaller part of the total. Much of it cannot be estimated in dollars and cents, for it includes, besides loss of life, the destruction of immature forests, reduction in timber growth, and damage to soil fertility, as well as the impairing of stream navigability and water-power resources. Of the whole number of fires, 14 per cent were attributed to railroads and 6 per cent to lumbering. Perhaps such percentages may not appear impressive, but it is to be borne in mind that if a method is devised which will prevent one fire, the cost of the research work may be amply justified, since damage amounting to hundreds of thousands of dollars may occur from a single fire.

NATURE AND COST OF WORK NEEDED

It is believed that in the beginning the tests should involve logging locomotives and donkey engines in some such way as outlined in a mimeograph entitled Proposed Tests of Spark Arresters, which is available at the Laboratory. Later, the tests might be extended to include common-carrier locomotives also. Factors such as size and type of engine, load, fuel, method of operation, temperature and humidity of atmosphere, and wind complicate the problem exceedingly. Such being the case, it is practically impossible to state how much money would be required for a thoroughgoing research, but at the outset we would estimate that perhaps $30,000 would be required, to cover a period of several years. Perhaps coöperation could be secured from manufacturers of logging equipment. Possibly one or more of the engineering colleges could assume parts of the work under a coördinated plan. The first step should be to determine the effectiveness of various spark arresters now in common use. With the information thus obtained as a basis, effort should then be directed to the development of improved types of appliances.

WHO SHOULD PAY FOR THE WORK

It seems logical that the expenses of research in spark arresters should be borne by one or all of the following:

a Endowments for mechanical research
b The Federal Government
c The forest industries, including manufacturers and users of logging equipment, the railroads, and timberland owners.

With respect to endowments, the Society could serve most effectively in finding out what funds could be made available and interesting the authorities who control such funds in the project.

With respect to the Federal Government, the Society could use its influence in favor of the necessary appropriation.

With respect to the forest industries, there will be a large amount of work to do, not only in getting them to share the cost of the work, but in enlisting their coöperation in testing existing equipment and any improvements which may be devised by research.

WHO SHOULD DIRECT THE WORK

We are convinced that the work should be directed by mechanical engineers, since it is essentially a mechanical-research problem. Such engineers should have the advice of practical foresters, loggers, and manufacturers and users of woods equipment, but this should not obscure the fact that the research itself is strictly mechanical engineering.

R. C. Hawley,[18] in commenting on Mr. Mathewson's paper, wrote that it was surprising that the author had not made any mention of several other original investigations bearing on the subject, which in two instances existed in published form. These publications were "Locomotive Sparks," by W. F. M. Goss, published in 1907, and "Fire Losses—Locomotive Sparks," by L. W. Wallace, published in 1923. The author was correct in stating that "many questions are still unanswered and require tests of fire-protective appliances." For example, the investigations of Goss and Wallace indicated that sparks capable of setting fires and which passed through the screens in the ordinary front-end arrangement were distributed for only a short distance from their source of origin. Unfortunately the range of conditions under which these tests had been made has been relatively so narrow that it was doubtful whether the conclusions had been accepted generally by foresters dealing with spark arresters and forest fires. Before the attitude of the foresters could be changed, tests as to the distribution of sparks of fire-bearing size under conditions of high temperature, low relative humidity of atmosphere, and high velocity must be made.

Undoubtedly there was abundant room for further experimentation in testing new spark-arresting devices, as well as in establishing the relative value of those already in use.

From the practical standpoint, however, namely, the prevention of forest fires arising from sparks cast by engines, the most important point to hammer home was that frequent and careful inspection coupled with proper maintenance was absolutely essential if any spark-arresting device was to function efficiently. What the situation needed more than research was immediate action in applying knowledge already existing.

The greatest service which the A.S.M.E. and other agencies, including the Federal Government, could perform was along educational lines, in convincing owners and operators of mechanical equipment casting sparks that: (1) Spark-arresting devices must be part of such equipment. (This is to a large extent accomplished); (2) such devices must be conscientiously inspected and maintained; and (3) that areas adjacent to equipment casting sparks must be kept in a condition of low inflamability.

Clyde Leavitt[19] wrote that many different kinds of spark-arresting devices were already in use on the railroads of this continent, some being much more effective than others. None of them, however, were fully effective, since steaming capacity was too seriously reduced when the point where there was no emission of incandescent sparks was approached.

In many cases the full efficiency of the spark-arresting device was not secured for lack of adequate attention by company employees to maintenance and repair. Many fires were due to defective nettings or fittings in front ends, rather than to inherent inadequacy of the equipment itself. Experience indicated that, as a general rule, if there was to be thorough efficiency in maintenance and prompt repair of fire-protective appliances, there must be an independent check inspection, by competent men, acting under authority of law, and representing the governmental organization having local jurisdiction. This applied to fire-protective appliances of ash pans, as well as of locomotives.

Some proportion of the fires attributed to locomotives were actually caused by the more or less common but reprehensible practice of passengers on trains throwing burning smoking materials from car windows or platforms.

Again, the existence of dry grass and weeds and of other inflammable matter on and adjacent to railway rights of way was a fruitful source of increased fire danger.

The character and quality of coal fuel in use was an important factor in determining sparking propensities of locomotives. Lignites and sub-bituminous coals, for example, possessed little or no coking properties and required smaller-mesh netting in the front end and a different regulation of drafting arrangements than did the bituminous or coking coals. Similarly, a high percentage of slack in coal fuel introduced another element of hazard, which required separate consideration.

It was apparent that with the best available spark-arresting devices maintained in perfect order, it was still possible for stack fires to occur, though under these conditions the fires would be

[18] Professor of Forestry, Yale University, New Haven, Conn.
[19] Chief Fire Inspector, Board of Railway Commissioners for Canada.

very largely restricted to periods of high temperature and low humidity, and to areas where highly inflammable debris existed in close proximity to the right of way.

In the oral discussion which followed, it was pointed at that fire prevention was above all a matter of care. D. A. Crocker[20] presented a similar point of view. During a recent fire-prevention conference held in Wisconsin, he said, it had been brought out clearly that in recent years on such railroads as the Northwestern, the number of stack fires had been greatly reduced due to efficient inspection methods. On the smaller roads, such as the privately owned logging roads, the decrease in the stack fires had been very slight because such methods had not been applied.

The author, in replying to Professor Hawley, said that he was familiar with the work of Messrs. Goss and Wallace, and thought their technique of experimentation meritorious. But while their work had been confined to bituminous fuels, the author had been giving consideration more particularly to conditions as they existed in the West, where the hazard was very great for two reasons: first, because of the inferior fuel, namely, lignite; and second, because of the very low humidities to be found in the West. He concurred with discussers fully as to the importance of careful maintenance.

High-Speed Induction Motors and Frequency Changers

UNDER this title Charles Fair[21] contributed a paper[22] making special reference to the application of such apparatus to woodworking, grinding, drilling and similar machines where high speed is of special advantage.

In discussing Mr. Fair's paper, Fraser Jeffrey[23] wrote that the first cost of frequency changers was an important factor in holding down the plant burden chargeable to the electrical installations in it. In the table given below it would be seen that the same output of frequency could be obtained with different combinations of driving motor and generator, and therefore that there would be considerable differences in the cost of the apparatus that might be used. For instance, it was obvious that for an output frequency of 120 cycles, the cost of a 4-pole driving motor and a 4-pole generator operating at 1800 synchronous r.p.m. would be less than that of an 8-pole driving motor and an 8-pole generator operating at 900 synchronous r.p.m. On the other hand, a 2-pole driving motor and a 2-pole generator operating at 3600 synchronous r.p.m. might not be any cheaper than the 4-to-4 pole combination due to the structural features of 2-pole machines. Outside of the 2-to-2 pole combination, however, the lower the speeds of the sets considered, the higher their first costs would be. The capacities of the sets under consideration would, however, have some bearing on the speed that could be used.

OUTPUT FREQUENCIES OBTAINED BY DIRECT-CONNECTED FREQUENCY CHANGERS, BASED ON A 60-CYCLE SOURCE OF SUPPLY AND SYNCHRONOUS SPEED OF DRIVING MOTOR

Number of poles of driving motor	Number of poles of generator					
	2	4	6	8	10	12
2	120	180	240	300	360	420
4	90	120	150	180	210	240
6	80	100	120	140	160	180
8	75	90	105	120	135	150
10	72	84	96	108	120	132
12	70	80	90	100	110	120

When the generator of one of these high-frequency sets was driven by a squirrel-cage induction motor, the regulation of the set might become important when consideration was given to outputs of fairly large proportions. This regulation would affect production to a certain extent as the speed of the motors driven from the set would be affected. Constant frequency could be maintained by the use of synchronous motors driving the generators, but the simplicity of such installations would immediately be lost. Regulation of squirrel-cage-motor-driven frequency sets was effected in two ways as follows:

1 Drop in speed of the driving motor as the load came on, with consequent drop in the output frequency of the generator
2 Drop in voltage of the output generator due to—
  a Drop in speed of the driving motor
  b Inherent regulation of the generator itself.

For example, with a small 35-kva., 100-cycle, squirrel-cage-motor driven direct-connected frequency-changer set operating without load, the output frequency of supply was practically 100 cycles and the voltage on the supply system was 405 volts. If the load taken from the set was small in proportion to its full-load capacity, the motors driven from it would operate very close to a speed corresponding to 100 cycles and with a slip corresponding very close to 405 volts. If the load taken from the set were now increased to full load, the output frequency would drop to close to 96 cycles and the slip of the motors would increase due to the decrease in output voltage to approximately 360 volts due the lower speed of the driving motor and to the inherent regulation of the generator itself. The drop in voltage could largely be taken care of by designing the motors that worked on the system accordingly, but even so there would be some difference in the speed of these same motors, which would be dependent on the load on the set. The frequency drop, however, could not be compensated for in cases where the motors on the system operated their loads direct, i.e., without a driving medium.

For increases in plant capacity and where more capacity of the same high frequency was desired, parallel operation of squirrel-cage-induction-motor-driven frequency sets might become a problem if the use of existing feeder circuits was contemplated. The driving motors of the sets must all operate at exactly the same speed, even to within a fraction of one revolution, and no two duplicate squirrel-cage motors would do this. Consideration would therefore have to be given to making the driving motor of the slip-ring type with external secondary resistance for controlling the speed, and hence the division of the loads within very close limits. Even this might need adjustment and might not be satisfactory from an operating point of view. Probably the best solution for this problem would be to have each frequency-changer set independent and driving its own particular group of machines through its own particular feeder.

W. A. Furst,[24] in a written discussion stated that an important point in connection with the use of the induction frequency changer was comparison of size and cost with those of the standard synchronous generator. It should be remembered that for any given size of frequency changer the power input was the same irrespective of the kilowatt-rating output at the various frequencies. The kilowatt output from the frequency changer was directly proportional to the increase in speed, and it was necessary for the motor to supply the additional power required to drive the frequency changer at the increased speed. For example, in the case of a combination of frequency changer and motor or motor-generator set of 10 kw. output at 120 cycles, the power input of this generator from the 60-cycle source of supply would be 50 per cent of the output or 5 kw. and the motor would supply the additional 5 kw. of the output as mechanical power at the generator shaft, neglecting losses.

If it were desirable to generate 180 cycles, the generator would still take 5 kw. from the source of supply, but the kilowatt output would be correspondingly increased in direct proportion to the speed required to obtain the 180 cycles; the generator would, therefore, take one-third of its output from the line and the motor would supply two-thirds. In this case the excitation from the line would be 5 kw. or one-third of the output. Therefore the output of the machine would be 15 kw. These figures were purely theoretical, and in practice it would be found that the output would vary somewhat, depending on the efficiencies of the driving motor and the frequency changer itself. In comparing this with the synchronous machine, the generator would have full capacity, or 10 kw. output. The driving motor, neglecting losses, would have the full capacity output (10 kw.). From the above comparison, it would be seen

[20] Forester, American Paper and Pulp Association, New York.
[21] Chief Engineer, Baxter D. Whitney & Son, Inc., Winchendon, Mass. Mem. A.S.M.E.
[22] Published in the Mid-November, 1925, issue of MECHANICAL ENGINEERING, p. 1012.
[23] Electrical Engineer, Allis-Chalmers Mfg. Co. Milwaukee, Wis.
[24] Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

that with 120-cycle output on the frequency changer the motor is just half the size it would be if it were driving the synchronous generator.

Another important item in connection with the use of the frequency changer was regulation. The regulation on either an induction frequency changer or an alternating-current generator was inherently poor. Where the induction frequency changer was used in large capacities some difficulty might be experienced in handling light loads, in case of overtime work in the plant, wherein the voltage might be rather high on the high-frequency side. This was one advantage of the use of the synchronous generator, in that the voltage might be regulated by decreasing the excitation on the generator field.

Objections were sometimes offered to the use of the induction frequency changer due to the low power factor produced on the 60-cycle line. When this was analyzed it would be found that the so-called low power factor was such a small percentage of the total, and even of the set itself, that it became a small item. This was especially true for the higher frequencies where the power delivered by the driving motor became a greater percentage of the total output of the frequency changer.

Where large capacities were required an induction frequency changer might be used driven by a squirrel-cage motor and a static condenser used to correct the power factor or a synchronous motor might be used to drive the frequency changer and also correct for plant power factor. Usually the combination of the induction frequency changer with even a 100 per cent power factor synchronous motor was a good combination in the industrial plant. The synchronous motor lent itself readily to obtaining an absolute constant frequency generated by the frequency generator. This was due to the fact that the synchronous motor having no slip while the squirrel-cage motor drove the frequency changer, the speed would vary with increased load so that a decrease in frequency output would result. Another important use of the frequency changer, was in obtaining various combination of speeds on either existing motors or other pole combination of motors over that which might be obtained with the existing plant frequency. For an example, with a plant using 60-cycle service it had been necessary to obtain a speed of 3000 r.p.m. on the motor. It might be readily appreciated that this was an impossible speed to obtain with any pole combination of motor on 60-cycle service. Therefore it was necessary to use a 4-pole motor driven from a 100-cycle source of supply. This made a good combination in that a 4-pole frequency changer was driven by a 6-pole motor. Another condition existed in the same plant wherein it was necessary to have approximately 2200 r.p.m. on the motor. In this case a 4-pole motor was used, driven at approximately 80 cycles. To obtain the 80 cycles a 2-pole frequency changer was used, driven with a 6-pole motor. This particular combination consisted of a 4-pole and a 2-pole frequency changer which were mounted on one bedplate and driven by the 6-pole motor.

In the oral discussion following, M. Lund[25] said the great objection that the woodworking industry had to changing their equipment to high-speed induction motors was the cost. In order to get these various frequencies it was necessary to buy electrical equipment whose cost was many times that of the operating machine. He thought that if a great many of the machine builders would confine themselves to 140 or 240 cycles, 7200 r.p.m., and 3600 r.p.m., they could adapt their cutting tools to those speeds and thus be able to reduce the initial cost to the purchaser a great deal.

G. H. Frew[26] said that in a good many of the woodworking plants the tendency was to have the machines operate at higher speeds than 7200 r.p.m., which required frequency changers. Most of these concerns had motor-driven apparatus arranged for 60 cycles. He would like to ask some of those who had had experience along that line, whether if they put in a frequency changer, they had to change their motor. He had installed a 120-cycle motor and run it on a 60-cycle current, and experienced considerable heating up. He also wished to know whether it was possible to make a motor which would fit in for 60 or 120 cycles or anywhere in between.

[25] Lund Engineering Works, Grand Rapids, Mich. Mem. A.S.M.E.
[26] Holliday Machine Works, Philadelphia, Pa. Assoc-Mem. A.S.M.E.

Mr. Furst stated that a 440-volt motor could not be operated at 120 cycles but that it could be operated at 220 volts at 60 cycles or even reconnected for 440 at 60, but the same motor could not be used on either 220 or 440 volts at 120 cycles. It would be necessary to take one at a base voltage of, say, 220 volts, 60 cycles, and operate it at the higher voltage at the higher frequency. There would be an objection to taking and operating it at 880 volts and 120 cycles, due to the insulation on a motor for that class of service, but for experimental purposes it would stand 880 volts, although he would not care to recommend it for continuous service.

Another objection that could be raised would be that trouble might be experienced with the underwriters if 880 volts were used through the plant.

C. W. Keuffel[27] wished to know what the recent developments were in the variable-speed handling of a.c. equipment.

The author, Mr. Fair, in his closure said that regulation could be held very closely on induction-type frequency changers. In fact, the General Electric Co. had standardized 15 per cent regulation as maximum regulation. Many of the frequency changers fell considerably below this. Since 15 per cent regulation meant 15 per cent between no load and full load, this was not so bad. Ten per cent was a fair average regulation within the working conditions. He did not consider two-pole frequency changers very good practice. As to the question of cost on frequency changers, Mr. Fair said that in some of the woodworking plants the question of installation cost was a question of paying the money or going out of business, under pressure from a competitor who could get out the product 50 per cent faster, with a much better finish. In woodworking and machine shops the cost of energy was roughly from one to three per cent of the production costs. If the production could be increased 10 or 20 per cent it would matter little if the cost of energy were doubled, as there would be an enormous reduction in productive cost, labor cost being roughly 50 per cent of total cost. With regard to the changing of motors from one frequency to another, Mr. Fair said that motors could be run up to their mechanical limits provided voltage were varied with the frequency; for example, a standard 220-volt, 60-cycle motor could be run at 440 volts, 120 cycles.

With regard to variable-speed a.c. motors, the author said that there were some very fine variable-speed, or rather adjustable-speed, motors. A.c. motors had for some time been built that operated practically with d.c. motor adjustable characteristics. Such a.c. motors were of the adjustable-brush type.

Ball Bearings and Roller Bearings on Railway Cars

A report by J. Klimes, C.E., published in No. 17 of the Public Works Review (Prague) describes the results of practical experiments which were performed during the past few years with railway cars provided with ball and roller bearings. Some of the data from this report may be of interest.

To find the number of cars by which a train may be enlarged when ball bearings on all axles are used, without any loss of energy and without changing the propelling power, the Swedish state railways dispatched two trains with engines of the same type over a track 205 km. long. One of these trains had 30 cars of the type used for the transport of iron ore, with usual standard bearings, and the other train had 39 cars of the same gross weight but all axles were provided with ball bearings. The trains made this run ten times and it was found that the ball bearings made it possible to increase the number of cars by 30 per cent without affecting the consumption of coal.

Of special importance are the ball bearings on long-distance express trains, where the danger of overheating is quite large. The rate at which ordinary bearings on railway cars overheat in Sweden is stated to be 50 in 100,000 axles-km. against 1.6 overheats in the case of ball bearings and none in the case of roller bearings.

In view of these favorable results the Czechoslovak railway administration had equipped some of its express trains with roller bearings.

[27] Keuffel & Esser Co., Hoboken, N. J. Mem. A.S.M.E.

Industrial Furnaces

Heat Losses, Products of Combustion, Fuels, Efficiency and Its Improvement, Automatic Control, Selection of Fuels, Etc., as Discussed at the A.S.M.E. Annual Meeting

THE SESSION on Industrial Furnaces held at the Annual Meeting of the A.S.M.E. on the morning of December 2, 1925, was devoted to the presentation and discussion of two papers of great interest to engineers having to deal with problems involving the design and operation of furnaces for industrial purposes. These papers, Industrial Furnaces, by W. Trinks,[1] and Industrial-Furnace Efficiency, by Victor J. Azbe,[2] appeared in full in the Mid-November, 1925, issue of MECHANICAL ENGINEERING.

O. P. Hood[3] presided at the session and, before introducing Mr. Trinks, commented on the failure of the combustion engineer to give his attention to the industrial furnace, his mind having been occupied to a very great extent by furnaces for steam boilers. He further commented on the lack of Society papers on the subject, and expressed the hope that the session would be the means of opening up this newer field of interest. It was not a difficult matter, he pointed out, to make output measurements on boiler furnaces, owing to the fact that the furnace was connected to a device which was easily subject to measuring operations, but it was quite a different matter to make a heat balance on a brick kiln or to determine where the heat losses occurred. Professor Trinks then presented his paper.

Theo. B. J. Merkt[4] contributed a written discussion of Professor Trinks' paper, in which he said that it was a peculiar coincidence that the session immediately following that at which Mr. Hoover had presented the value of research in pure science should discuss a subject which had had the benefit of very little coördinated effort in this direction.

Mr. Merkt had been somewhat surprised to find Professor Trinks disowning, in his title, the parentage of many children who had sought the protection and care of the industrial fuel engineer for years. However, he perhaps had wished to stir up discussion of this point, and therefore Mr. Merkt was keen to learn why his definition of industrial furnaces was so limited.

It was sad, but true, that, as stated, fuel economy was so strongly stressed in comparing the various forms of fuel energy and so little value or attention given to other costs and factors incidental to process work. Just as a CO content of 2 to 4 per cent had been said to be frequently necessary in heating steel, there were many other processes demanding similar furnace atmospheric adjustments which might be oxidizing or neutral, as well as reducing.

In choosing the fuel for such exacting work it should not be forgotten that automatic control of temperatures must be considered if production was to be standardized for a given process.

In obtaining the costs entering into the heat processing of an article there were a thousand and one things to be considered, and those engaged in such work had been hampered by the lack of a heat-processing code which would help them in arriving at cost figures for the utilization of various fuels.

The investigation of this subject by the Fuels Division was something which must be done sooner or later if not alone fuel waste, but that economic loss caused by improper furnace selections and process layouts, were to be prevented.

Following Mr. Merkt's discussion, Chairman Hood called upon Gordon M. Peltz[5] for comment. The first point discussed by Mr. Peltz was the leakage of gases through the walls of industrial furnaces. He said that in glass works, particularly, the furnaces were laden with gases which might affect very seriously the refractory material as they were forced through the walls of the furnaces. In this connection he mentioned an instance in which gases of a pure nature at furnace temperatures condensed at a red heat, the result being that they passed through the first six inches of brickwork, condensed at the lower temperature, and corroded the inner layers of brick. From outward appearances, however, the walls of the furnace were in good condition, but closer examination disclosed the fact that the heart of the wall was gone. Mr. Peltz referred to the statement in Professor Trinks' paper that furnace pressures of the nature of 0.02 in. of water had been recorded, and stated that he had actually measured pressures as high as 0.25 in. with unusual conditions, the condition in this case being a furnace 25 ft. in height from the bottom of the flues to the highest point, which necessarily meant that either the top of the furnace must be under pressure or the bottom under vacuum.

Another important effect which might result from leakage mentioned by Mr. Peltz was that of temperature distribution. It was obvious, he said, that if excessive leaks occurred in one portion of a furnace, it had the effect of an extra flue which the designer had not figured on, and, if the pressure in the furnace changed, more or less heat might escape through that unintentional flue and throw a portion of the heat in that direction.

In connection with Professor Trinks' remarks on the selection of fuels, Mr. Peltz stated that the plant with which he was associated had found it desirable to maintain no less than seven complete fuel systems in addition to the regular stoker-fired boilers. These consisted of the following: A complete raw-gas system used in the main unit, a clean-gas system, carbonated-water-gas, natural-gas, and three fuel-oil systems ranging from heavy oil to distillate and even kerosene. In addition to these, experiments were being conducted on electrical heating. The speaker stated that each of these systems had its particular place, where no other system would fit quite so well, and yet there were problems which required further investigation to produce the results most desired.

A written discussion of the two papers was then presented by J. A. Doyle.[6] In the course of his comments, Mr. Doyle said that the authors had rendered a distinct service, particularly in stressing the economics of the industrial heating problem as a whole. This important point was frequently lost sight of in the technical tanglefoot represented by the data usually considered in discussion of applied thermodynamics with reference to industrial heating operations.

When one considered the influence of heat upon the quality and cost of practically all products manufactured in the metallurgical, ceramic, and chemical industries; the pressing demand for better quality of products subjected to heat-treatment processes; the comparatively inefficient methods of heating, cooling, and handling in general use; and the more or less misdirected effort and conflict of ideas in favor of some one form of fuel, or electricity, as a solution for industrial heating problems, it was apparent that, to effect improvement of industrial heating practice in the future, it was necessary to encourage a better understanding of the underlying principles governing the practice of the art on the part of engineers concerned with the selection of methods and equipment suitable for the proper conduct of specific heat-treating operations.

The term "efficiency" could not be defined as accurately in industrial heating operations as in the field of power or illumination. The term should include consideration of the quality of the ultimate product, and the factors that affected quality both in heating and in cooling. Without reference to the quality phase of the equation, figures on cost of production were of doubtful value. The factor of quality could not be stressed too strongly, not only because of its influence on the cost of the heat-treatment process, but because of its bearing on the cost represented by the ultimate service of the product itself.

The engineer, as a rule, was inclined to interpret the expression "efficiency" in terms of fuel consumption, output, temperature con-

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[6] Vice-President, W. S. Rockwell Co., New York, N. Y. Mem. A.S.M.E.

trol, power, labor, etc. Changing conditions supporting the demand for better quality of heat-treated products, prompted the suggestion that the metallurgist and the chemist should have something to say about the methods of heating and cooling from the standpoint of quality, and that the problem of the engineer was that of cost from the standpoint of production based on fundamental requirements dictated by the metallurgical or chemical requirements of the product to be heat-treated.

Development of the art, in light of past experience, suggested abandonment of some of the present-day technical standards and the substitution of other standards that would more properly measure the result actually sought, i.e., the quality and ultimate cost of the finished product. There were many factors entering into determination of this point, any one of which might affect the ultimate result.

The notion that any one form of fuel, or electricity, or furnace had a monopoly on the factors governing the quality and cost of the ultimate product, should give way to a more reasonable perspective of the problem as a whole. Each form of fuel, or electricity, and furnace had its limitations as well as its field of usefulness. The problem of selection was that of determining a suitable combination which, when properly applied, would best meet the requirements of the individual case.

The price of fuel, or electricity, was not equivalent to the cost of heating. The manner of applying the heat, the amount of energy used, and the method of handling the product to be heat-treated were the determining factors, the control of which was more a matter of furnace design and operation than the form of fuel or electricity used for releasing the heat. Electricity, even at a higher price on the basis of energy cost, was frequently preferred to any form of fuel, just as the more expensive fuels, such as gas or oil, were frequently preferred to coal.

The manner of transferring heat to and from the product to be heated or cooled was basic. The method of cooling was frequently just as important as the method of heating. We were concerned more with the manner of heat application than with the manner of heat generation, whether it be with fuel or electricity, from the standpoint of quality; and, with the method of heat utilization and method of handling the stock to be heat-treated, from the standpoint of cost in which the price of fuel or electricity was but one of many contributing factors.

Control of furnace temperature, said Mr. Doyle, was but a part of the process of heat treatment. Control of time, rate, and manner of heating or cooling, and the methods of loading and handling were just as essential as control of temperature. The real test, from the standpoint of control, was the uniformity with which the product was heated and cooled when the furnace was being operated at capacity.

Selection of industrial heating equipment adapted to any method of heating, cooling, and handling, or to any form of fuel, or electricity, should be based upon consideration of the many factors affecting the quality and ultimate cost of the heat-treated product. Selection was, as a rule, largely a matter of compromise between the ideal and the practical, and could be most advantageously effected by a free and frank interchange of ideas between the metallurgist or chemist concerned chiefly with the quality of the product; the plant engineer concerned with the problem of production under variable operating conditions; and an experienced furnace engineer free from preference or prejudice for or against any one form of fuel or electricity or equipment, and capable of viewing the problem in economic perspective from the standpoint of the manufacturer who, ultimately, paid the bill.

W. B. Chapman[7] wrote that the author's comparison of boiler furnaces and industrial furnaces was ingenuous. The total quantity of fuel used in each of the two fields was probably not far different, but the improvements possible in one field far outweighed the possibilities of the other.

If the average boiler-furnace efficiency was 75 per cent and the average industrial-furnace efficiency 15 per cent, which was not far from the case, it was high time that those who would preach fuel conservation should turn their attention to the more wasteful of the two fields.

[7] President, The Chapman-Stein Furnaces, Mt. Vernon, Ohio. Mem. A.S.M.E.

Probably over one-half of the industrial furnaces in use today had been designed in large part by boss masons totally ignorant of the velocities of the gases at any of the critical points. This question of velocities was not mentioned in Professor Trinks' paper as a point to be considered, but Mr. Chapman's company found in a large number of cases that it was of the utmost importance. For example, gases transferred their heat to best advantage when moving at velocities within certain limits, also the air passing through the preheating chamber took up the heat best when moving at velocities within certain limits. Moreover, through all of the various ports, flues, and chambers there were certain desirable velocities which should be observed. The failure of many, if not indeed most, furnaces had been due to ignorance regarding velocity limitations.

A few years ago, Mr. Chapman had seen a "home-engineered" continuous furnace which had been designed so that the velocity of the gases passing through it was so slow that the heat stratified and rose to the crown far above the steel, while the steel itself was enveloped in gases actually below the temperature required for rolling. On figuring out the cross-section of the furnace and the volume of gases passing through, it had been found necessary to lower the crown 50 per cent in order to bring the velocity of the gases within the limits necessary for efficient heat transfer. When making a study of a furnace for a specific purpose, special consideration should be given to the velocities at all critical points; bearing in mind, of course, special requirements for operating both at over and under capacity.

In addition to the points suggested by Professor Trinks, attention should be called to the importance of properly coördinating the ports with the quantity of fuel to be burned, the air required for combustion, and the pressure and temperature of both the fuel and air, each of which played an important part in the flame development. Further, the possibility of streamlines of heat, the shape of the arch, the fuel downtakes, and dead end should receive their share of attention.

Professor Trinks gave the impression that the use of preheating devices was looked upon with apprehension, due to the additional engineering problem involved when the air was preheated to a high degree. This had been particularly true a few years ago, but the situation was rapidly changing. Five years ago there had been practically no recuperators in use in this country preheating the air to over 500 deg. fahr. Now there were at least one hundred that were preheating the air to over 1500 deg., with corresponding increase in efficiency.

The first consideration in a furnace was the same as in any piece of machinery, namely, reliability. In the past it was true that the recuperative furnace had not been as reliable as desired. Some recuperators had been made of metal which cracked when subjected to high temperatures; others had used high-temperature cement in such a way as to produce a monolith which would not stand unequal expansion. Still others had been made with vertical joints which, when expanded with heat, would not close again automatically as did horizontal joints. These problems, however, were now pretty well solved and the question of reliability need no longer be a deterrent.

Now that the recuperative furnace had become commercially practical, a large field had been opened for fuel saving. Heretofore preheating had been limited largely to the regenerative or reversing type of furnace, which was rather expensive and only applicable to large-sized units. A recuperator, on the other hand, could be applied to furnaces having a hearth area of only a few square feet. In France recuperators had been successfully applied to furnaces having a hearth area of but 2 sq. ft.

Many and large economies were possible in industrial furnaces, said Mr. Chapman in conclusion, but the field that held the most of promise for the immediate future was the application of a reliable recuperator to the many purposes for which it was peculiarly adapted.

At the chairman's request for further oral discussion, Howard Butt[8] called attention to the need for concentration on particular types of furnaces and solving the problems involved, in order that the products might be more accurately classified. To strengthen his point, he stated that Charles M. Schwab once made the statement

[8] Sanford Riley Stoker Corp., Worcester, Mass. Mem. A.S.M.E.

that 97 per cent of the steel manufactured in the United States was not alloy steel. He considered the subject of fuels for furnaces a rather broad one, and recommended that there be a definite classification made, such as coal-fired furnaces, producer-gas-fired furnaces, or oil-fired furnaces.

C. C. Trump[9] mentioned the rather broad title used by Professor Trinks and wondered if he would be willing to include in industrial furnaces those furnaces used in the distillation industry. He mentioned the fact that in this industry it was necessary to use all kinds of fuels, changing from one to the other as the economic conditions changed. The recirculation of hot gas had been found desirable to maintain certain furnace conditions, he said, producing a good fuel condition without excessive temperatures and permitting accurate temperature control. The speaker wondered if this practice had ever been adopted in industrial furnaces.

Speaking further on temperature control, Mr. Trump expressed a preference for what he termed a control which floated. In other words, a control which did not turn the heat all on or all off. In this connection he mentioned the development of thermoelectric controllers, which accomplished the results desired.

In line with Mr. Trump's remarks on the furnace for the distillation industry, Chairman Hood mentioned work of the Bureau of Mines on the distribution of heat in an oil-still furnace, and expressed the hope that this information might soon be available.

Commenting further, Chairman Hood stated that, owing to free circulation, a boiler was able to take all the heat applied to it, but in an oil still a certain maximum temperature must not be exceeded, and the one hot spot approaching that maximum really determined the rating of the still. These conditions, he said, emphasized the importance of correct design, the change from the old order of things in this particular industry resulting in an increase of one-third in capacity and decreasing the time involved.

Albert A. Cary[10] stated that in his 27 years of experience he had found that, even when the per cent of gain in efficiency was small, greater efficiencies were always desirable, since they resulted in more uniform products, due to the greater uniformity of the combustion of the gases, which influenced the uniformity of temperatures obtained.

Mr. Cary emphasized the importance of leakage, pointing out that infiltration of air caused a greater escape of hot and unburned bases to the flues, to say nothing of the dilution of the gases in the furnace and the consequent lowering of temperatures. He recommended taking samples of gas at the furnace and the flue outlet, as well as the temperatures at both ends of the furnace, and in this way definitely determining the amount of heat delivered to the product. There seemed to be a tendency, he said, to shift the responsibility from one to the other on the part of the chemical and mechanical engineers, with the result that progress was retarded. He stated that he had found it possible to make the necessary measurements quickly and sufficiently accurate for all practical purposes, and by keeping a log sheet handy could determine the performance of the furnace at a glance.

A. E. Walden[11] was of the opinion that the weight of material handled greatly affected the efficiency of the furnace. He mentioned a furnace in which formerly 65 lb. of bolts were treated to the gallon of oil, the production later being increased to 120 per gallon as a result of certain changes in the furnace. He also mentioned an electric enameling furnace in which the cost for current was about four times that for oil used in a former furnace, but no record of weight of material was kept, so there was no means for determing the weight of product per kilowatt-hour in comparison with weight per gallon of oil consumed. Before leaving the subject he asked Professor Trinks for a statement of the relation between the furnace pressure and the furnace atmosphere, which the author touched upon in his closure.

In connection with the furnace atmosphere, S. E. Friedeberg[12] said that he thought some definite statement should be made covering kilns for ceramic work. He mentioned the fact that in certain types of kilns it was not possible to use a reducing atmosphere. He felt that there should be a statement as to which types of kilns might use a reducing atmosphere and which should be operated on an oxidizing flame. As an indication of the importance of this question, he mentioned his experience with various kinds of glass, which, if mixed in the proper numerical order, permitted the use of a reducing atmosphere, but if the order was not adhered to the product was very inferior. The same thing, he said, applied to intermittent-oil-fired enameling furnaces.

In further discussing the paper, J. A. Doyle stated that the question of bright annealing with hydrogen was more or less common in this country, as was also the matter of circulation of gases, already mentioned. In discussing oil stills, he urged that they be brought within the industrial heating field, for one of the big problems was to determine whether a large pot of oil was needed, or if it was to be heated by passing it through pipes in rapid circulation. Regarding the reference by Mr. Waldron to the treatment of bolts, Mr. Doyle spoke vigorously against establishing the standard of output against fuel, the quality of the product being, in his opinion, of paramount importance.

Discussion of Mr. Azbe's Paper

The paper by Victor J. Azbe was presented at this time, following which Mr. Doyle remarked further on the subject of better products. He cited conditions in the brick-manufacturing industry, referring particularly to the great quantities of building bricks brought from the Middle West rather than accept those made on the Hudson River, simply because a better and cheaper product could be had by shipping from a point farther from New York. He urged the mechanical engineer, in his work in this newer field of industrial heating, to avail himself of the experience of men in the field who had broad experience and who, he felt, would be pleased to cooperate. Finally, he said, the term "efficiency" must include not only better methods of heating, better methods of cooling, better methods of handling and a cheaper product, but always there must be an eye to the quality of the product.

In reply to a question by Mr. Friedeberg as to how the air pressure under the producer in the operation of coal distillation was increased, Mr. Azbe replied that a blower was used. While, he said, the gases left the kiln at 1600 deg., they were immediately mixed with air before going to the producer, enabling the blower, which could safely handle gases at 500 deg., to perform its work in a satisfactory manner.

Charles H. Bigelow[13] felt that too much emphasis could not be placed on insulation against heat losses. He cited instances where heat had been allowed to escape from steam lines and furnaces, and mentioned the saving effected by proper attention to insulation. One case he spoke of was that of heat conservation in a turbine installation. In this instance the heat was deflected against a fan and driven into a furnace.

In emphasizing efficiency, H. W. Brooks[14] introduced a new term, "dollar efficiency." To illustrate, he drew the mental picture of a pitcher inclined to pour its contents into a glass. A hole in the bottom represented the loss. The contents he referred to as dollars, or B.t.u. which represented dollars, and he called attention to the more rapid turnover possible with smaller losses through the hole in the bottom of the pitcher, which might be reduced through closer attention to efficiency.

J. W. Mershon[15] mentioned the work of the Yale & Towne Company in annealing iron castings. He said that up to three years ago the oil furnace had been used for this work, but after experimenting with oil, gas, and electric furnaces the latter were finally decided upon. In this type of furnace it was found that the dollar efficiency was greater, owing to the fact that it was able to transfer the heat of the treated castings to the incoming work, whereas in the oil furnace it was necessary to pack the castings in the furnace, wasting a great deal of heat as a result. A further saving in labor resulted from the fact that packing was not necessary in the electric furnace, due to the gradual heating, which was not possible in the oil furnace.

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[10] Consulting Mechanical Engineer, New York, N. Y. Mem. A.S.M.E.

[11] Ch. Engr., Wehr & Walden Engrs., Baltimore, Md. Mem. A.S M.E.

[12] Supt. of Erections, Industrial Furnace Dept., Combustion Engineering Corpn., New York, N. Y. Jun. A.S.M.E.

[13] Plant Engr., Spicer Mfg. Corp., S. Plainfield, N. J. Mem. A.S.M.E.

[14] Consulting Engineer, Fuller Lehigh Co., Fullerton, Pa. Mem. A.S.M.E.

[15] Assistant Superintendent, Power and Plant, Yale & Towne Mfg. Co., Stamford, Conn. Assoc-Mem. A.S.M.E.

The operator was a very important factor in the struggle for efficiency in many cases, according to David Moffat Myers,[16] who mentioned a plant using powdered-coal burners which had been giving very poor results. In investigating conditions he had found that the burners were functioning very poorly, and after a tour of the plant and making adjustments had succeeded in cutting down the coal consumption 30 per cent. Upon inquiry he had found that the operator was an old man, entirely unfitted for the work. The substitution of a man with knowledge of combustion and capable of properly regulating the equipment had resulted in a fuel saving of 45 per cent.

Albert A. Cary also emphasized the human equation in furnace operation. Unfortunately, he said, when trouble developed in connection with a plant a young engineer just out of college, with no practical experience, was called upon in many instances to make tests to determine the cause of the difficulty. The young man was capable of making the tests in an approved manner, but was not able to continue with the problem and work out the solution. He left the measurements and test data for some one with more practical experience to analyze. Mr. Cary recommended the employment of men capable of making the necessary tests, and then operation of the plant until the desired results were secured. He then spoke of what he termed "freak designs," and mentioned tests which he had conducted on them. In one case it was found that with the increase of pressure, with the consequent rise in temperature, nitric oxide was produced. It was found that if the pressure could be increased sufficiently it was probable that sufficient ammonia could be produced to make it a valuable by-product for fertilizer.

Another interesting discovery was that by separating the oxygen out of the air by centrifugal force it was possible to load the air to the furnace with additional oxygen and thereby increase the temperature to 200 to 300 deg. above the normal operating temperature.

At this point J. F. Barkley[17] mentioned his experiences with steel furnaces in the Pittsburgh district. He said that it was quite desirable to watch the quality of the product, but the fuel consumption also must not be lost sight of. The existing furnaces were operated on various kinds of fuel and in some cases the operation was so bad that it was not considered worth while to install testing instruments. However, when it came time to design new equipment, the quality of product was given first consideration, but very careful consideration was given to fuel economy also. The poor design of many of the old furnaces, he maintained, was the cause of the prevalent tendency to slight the fuel economy and devote most of the attention to quality of output. The loss or gain of a few per cent might determine positively whether or not a dividend was paid. He believed that it would be profitable in many cases to scrap the old furnaces and install equipment of high efficiency.

Professor Trinks, although he congratulated Mr. Azbe upon his emphasis of efficiency, stated that one must be very careful in the application of the word. In connection with Mr. Azbe's argument for the insulation of flues carrying producer gas, he mentioned an installation in which the flues had been insulated by placing them underground. The result was that trouble arose in the cleaning of the flues. The soot could not be blown out, because it was mixed with enough tarry matter to be slightly sticky; it had to be shoveled out. This method of removal could be applied only when the plant was shut down and the flues were cooled off, that was to say, over Sunday. Even then the flues did not cool sufficiently to allow a man to enter, unless they were flooded with water. The water-soaked bricks sent water vapor into the producer gas on Monday and Tuesday. On Wednesday the furnace worked well. From Thursday to Saturday the soot collecting in the flues gradually reduced the capacity, and on Sunday the cycle was repeated all over again. The original designer probably felt very proud that he had placed the flue underground where it was insulated against heat losses.

Speaking of recuperators, Professor Trinks said that they were very desirable in steel plants, but that sad experiences in heat salvage by recuperation had driven many engineers to the point where they would rather get along without recuperators. He stated that he knew many furnaces in the Pittsburgh district in which the recuperators were either badly cracked or else burnt out, and were, in consequence, out of commission. He expressed the hope that the future installations would prove more satisfactory. The waste-heat boiler was valuable, he said, where the "dollar efficiency" was high enough, but many plants in the Pittsburgh district had abandoned them and substituted a large central boiler plant with automatic stokers and expert attention as being more desirable than a haphazard maintenance of several small waste-heat units.

Insulation, he said, unfortunately could not be applied where it was most needed. In open-hearth furnaces, for instance, the conservation of heat caused melting of the brickwork. If it were possible to build a wall that would withstand temperatures of from 3000 to 3300 deg., it would be a real saving to insulate them; until then we must, of necessity, work uneconomically.

E. Rinehart[18] expressed the opinion that it would be desirable to remove the heat, rather than retain it within the furnace walls, by circulating water or air between the furnace wall and an outside insulated wall. He asked for the opinion of others on this matter.

Howard Butt[19] stated that in the making of sheet steel, temperatures of about 1400 deg. were carried with a very smoky flame. He said that it would be possible to control the temperature of the furnace and the character of the flame, but the quality of the heat might not be that most desired. He was of the opinion that the operator must use his judgment, much as a baker making biscuits.

Professor Trinks replied that the more up-to-date furnaces for the manufacture of sheet steel were operated on clean producer gas or natural gas. It was possible in these furnaces absolutely to control the temperature and relieve the operator of the responsibility, thereby insuring a uniform product. Many of the defects in sheet steel, he said, were directly traceable to the eye of the heater, which had been used for both pyrometer and flue-gas analyzer. He further stated, in reply to a question by Mr. Butt as to why some plants continued to use the old method when combustion engineers advocated the automatic control, that the dollars and cents invested and the fact that our grandfathers found it a desirable practice had much to do with the attitude.

H. A. Deuel[20] said that many plants at one time adopted furnaces burning coke-oven gas, but the poor quality of the product had driven some of them to the old hand-fired coal-burning ovens.

Albert A. Cary emphasized the design of the furnace as a means of controlling the action of the heat on the walls in refractories. In powdered-coal burners he recommended the forcing of the ash beyond the zone of high temperature. In oil burners, ample volume of furnace was found to be desirable.

In reply to W. R. Chambers'[21] question as to the dividing line below which temperature recirculation was desirable and above which it could be ignored, Professor Trinks stated that he had used it from 1600 deg. down. At 1600 the necessity for recirculation was comparatively small, at 1400 it was a bit greater, at 1200 it was almost necessary, and at 1000 it was absolutely necessary. It was impossible to draw a sharp line, he said, but the lower the temperature the more desirable was recirculation.

W. R. Clark[22] referred to the influence of "dollar efficiency" in the brass industry, which had almost entirely adopted the electric furnace for melting, greatly reducing volatilization and refractory costs.

Mr. Trump mentioned the practice of lime manufacturers, who, in the case of kilns with internal fuel, fed the stone in at the top and removed the lime at the bottom, the rising hot gases gradually bringing the incoming stone to the desired heat. As a further means of conserving heat, he suggested making the walls tight enough to prevent leakage and leading the air into the furnace at the point where the lowest temperature existed, bringing the furnace back to the point of combustion. The practice of cooling the walls with outside air was wasteful, he said, for the heat was carried away.

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[19] Sanford Riley Stoker Corp., Worcester, Mass. Mem. A.S.M.E.

[20] Superintendent, Practice Dept., South Side Works, Jones & Laughlin Steel Corp., Pittsburgh, Pa. Mem. A.S.M.E.

[21] Assistant Chief Engineer, American Steel Foundries, Chicago, Ill. Mem. A.S.M.E.

[22] General Works Manager, Bridgeport Brass Co., Bridgeport, Conn. Mem. A.S.M.E.

Plant Efficiency

Problems Affecting Plant Efficiency, Including Selection of Site, Plant Design, Site Limitations Affecting Layout, Etc., Discussed at the A.S.M.E. Annual Meeting

THE SESSION on Management at the A.S.M.E. Annual Meeting, on the afternoon of December 3, 1925, was held jointly with the Taylor Society, R. T. Kent, chairman of the Management Division of the Society, presiding. A paper dealing with problems vitally affecting plant efficiencies, prepared by Harold T. Moore[1] under the title, Influence of Plant Design on Plant Efficiency, was presented by Alfred Iddles[2] and discussed at considerable length. This paper appeared in the Mid-November, 1925, issue of MECHANICAL ENGINEERING, page 1059.

Cyrus McCormick, Jr.,[3] submitted a written discussion in which he stated that his company had found that one-floor layouts were preferable, with the machinery grouped so that the material passed from the raw state to finished product with a minimum of haulage. Next to machine arrangement he considered time of operation most important. Where possible, operators were required to attend more than one machine or perform gaging or testing operations, the latter eliminating defective parts at a point where the least amount of labor had been performed. This not only eliminated a department, but cut down expense incidental to the rejection of finished parts. Another saving resulted from the elimination of unmatched unit storages.

Mr. McCormick also considered correct lighting very important and recommended night lighting closely approximating daylight so that two shifts might be used with maximum results with a minimum of space and equipment. While, he said, it was infinitely preferable to start with a new plant, great improvement in efficiency could be effected in old multiple-story plants by arranging the lighter assembly work on the upper floors and the heavier assembly on the ground floor. Correct lighting installations also added to the efficiency, and additional area might be secured by roofing over space between existing buildings.

J. J. Swan,[4] in a prepared discussion, referred to the popular belief that economical production could be effected by large plants only, and stated that it had been comparatively easy to obtain financial participation by the public in these large enterprises because of this belief. However, he said, Government statistics showed that the small manufactories were far in the majority, and, despite more uneconomical operation, were making more money than the larger concerns. He recommended the application of economies practiced by the larger concerns, in order that the small companies might be made to prosper in a greater measure and be able to meet rising production costs, for large organizations had once been small ones which had been able to elevate their positions through profits derived from operation. Many of the large concerns, he said, were composed of small units efficiently operated and controlled by a central executive group.

Mr. Swan also mentioned the part played by plant layout, citing the case of a large organization which had engaged an expert to design a "model plant." There had been an excess of "lost motion" in the finished plant, much carrying of materials by truck and elevator, greatly cutting down profits and slowing up production. A new plant manager had relocated the machinery and reduced the trucking to one-third the former figure and the elevator travel to one-fifth, other improvements following in about the same ratio.

He emphasized the importance of studying the problem at hand and urged the consultation of an outsider with no interest other than designing a correct plant, likening the case to that of a doctor or specialist able to see the symptoms in their true light.

Tyler Stewart Rogers,[5] in a written discussion of the paper, said that plant owners had not had demonstrated to them the actual beneficial influence of good plant design on operating efficiency, and emphasized the importance of wider appreciation of the subject. The tendency of many plant owners, he said, was to neglect refinements as long as the plant paid dividends.

To illustrate the advantages of efficient plant layout, Mr. Rogers cited the case of a textile mill in which no columns were placed within the room space. The building, which was 102 ft. by 356 ft., had a sawtooth roof, and the absence of columns permitted the installation of 17 per cent more equipment than would have been possible with the usual type of construction. A printing plant with a floor area of 27,000 sq. ft. and a sawtooth roof required but three columns, allowing the installation of 25 per cent more equipment than a building with the usual number of columns. A radio manufacturer eliminated over 70 per cent of the columns ordinarily used, thereby permitting expansion and transfer of departments without fitting machinery within a forest of columns.

Limited column spacing also might spell economy, Mr. Rogers said. To illustrate, he mentioned a plant in which the column centers of a new building had been fixed at 20 ft. Investigation showed that machines requiring 16 ft. of space were to be used, whereupon the spacing was placed at 16 ft., saving 72 ft. of building width and 4000 to 5000 ft. per day in trucking raw and finished materials. The superintendent had no other explanation for the 20-ft. spacing than that it looked better.

The general shape of a building might also affect the plant efficiency, said Mr. Rogers. To illustrate, he mentioned a spinning mill constructed with the unusual width of 121 ft., the usual width, because of lighting, being 80 ft. The new width allowed three rows of machines to be installed as compared with the usual two rows, effecting a saving of 5 to 10 per cent in floor space and a considerable saving in labor, due to the greater economy of units of three machines over two. To provide adequate lighting, the floors beyond the last row of columns were cantilevered and steel sash provided from bench height to ceiling the entire length of the building, resulting in 100 per cent glass area above bench height. It was found also that the cantilever type of construction cost considerably less than the usual concrete construction, the saving in the case mentioned more than paying the fees of the industrial architects and engineers.

To illustrate the possible benefits of good planning in the design of mechanical equipment, Mr. Rogers mentioned a case involving a large dye house. Steam at 165 lb. per sq. in. was delivered to the kettles in the dye house. The plant engineer gave as his reason for the high pressure that the foreman demanded it. The foreman replied that he did not need it, stating that he had to take what the plant engineer supplied. The installation of a pressure-reducing valve permitted two boilers to be shut down, the fuel saving more than paying for the advice of the expert. Good advice at the start would have resulted in a saving over a great number of years. In another dye house the same expert was able, by installing temperature-control devices, to secure better results at 200 deg. fahr. than at the old temperature, 212 deg., used for years. A great saving in fuel resulted. Condensed steam from other processes was delivered direct to the dye vats in another plant and the steam consumption in the dye house cut off entirely.

The matter of routing parts through the plant, Mr. Rogers said, could best be solved by giving attention to the weight of the various parts and the work required upon them. Heavy parts should be moved as little as possible, while those parts requiring little work, of small size and weight and few in number might be moved greater distances. A diagram showing weight and bulk of parts and their movements between departments was recommended to quickly indicate the correct relationship of the departments.

Mr. Rogers also discussed the sizes of departments, mentioning the practice of placing machines close together and providing for their removal for repairs rather than allowing space for this work around the machine. Sufficient aisle space should be provided for stacking the work in process, he said.

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[2] Chief Power Engineer, Day & Zimmermann, Inc. Mem. A.S.M.E.

[3] Vice-President, International Harvester Co., Chicago, Ill.

[4] Associated Engineering Business Exchange, New York, N. Y. Mem. A.S.M.E.

[5] The Ballinger Co., Architects and Engineers, New York, N. Y.

Accurate balance was emphasized, the ideal condition being the delivery of the right number of parts to the assembly department each day, and the program so coördinated that all parts would move directly into assembly and thence to the shipping room and out of the plant.

John A. Willard[6] wrote that taxes should not be neglected and recommended placing them under Item 10 of the paper, "Cost of Real Estate." They were a very important factor in the consideration of a building site, he said, chambers of commerce often making special arrangements for the remission of taxes for a period of years as an inducement to manufacturers to locate in their community. Insurance also must be considered when deciding upon a location, he pointed out, for many insurance companies, especially in cities, considered the exposure hazard when fixing the rate.

Mr. Willard considered the analysis of process requirements of very great importance. He mentioned a plant in which this problem had been given more than usual attention, the investigation having been carried beyond the determination of machine capacity and a study made of the possibilities of standardizing the work of all departments and placing them on an incentive method of wage payment. Changes in three departments resulted in a reduction of 50 per cent in floor space and marked improvement in machinery placement.

In closing his remarks, Mr. Willard emphasized the part played by the conveyor in modern plants, and expressed the belief that the future would show a marked increase in attention to this important phase of plant design.

In discussing the paper orally, Charles H. Bigelow[7] called attention to the importance of head room, its effect on shafting, belting, etc. Lack of attention to this point might result in difficulties, he said. He also urged close attention to the labor market, mentioning the fact that the importation of labor from a neighboring city presented different problems from those encountered when men were selected upon application at the plant, the necessity of transporting the men in the former case being the source of possible trouble.

Robert E. Newcomb[8] felt that it would be wise to consider the environment of an old plant before moving it to a new site and new environment for the sake of better raw materials at a lower rate. He further recommended the use of wooden models in addition to templets for locating machinery, being of the opinion that they would help to visualize the problems under consideration.

In connection with transportation, Mr. Newcomb emphasized the importance of considering the time required for loading and unloading. He said that it was sometimes advisable to sacrifice the regular flow of materials through a plant in order to gain an advantage in storage or loading and unloading. In this connection he emphasized the desirability of devising machinery to eliminate individual operations which might be subdivided on several machines.

Roy L. Meeker[9] was interested in the manner most effective for getting the message of plant efficiency to the men who most needed it. He said that in his work as Secretary of Labor and Industry of the state of Pennsylvania he had encountered many plants, both large and small, which were far from efficient, mentioning particularly railroad shops in which, because of lack of necessary capital to make desired changes, the labor force wandered back and forth in the pursuit of its regular work, involving a time and energy consumption sufficient to cover about 25 per cent of the labor costs of the output of the entire plant. Further, he said that the prevention of accidents was largely dependent upon plant design, involving lighting, location, and facilities for routing the work.

In calling for the author's closure, Chairman Kent asked for an answer to a question propounded by C. E. Davies[10] as to fire losses, which in 1924 amounted to $500,000,000. Mr. Davies wished to know what steps should be taken to offset fire losses in industrial plant design and layout.

In his closure the author dealt with Mr. Davies' question regarding fire protection and the steps that were being taken in building design to reduce fire hazards and the enormous annual loss from conflagrations.

The National Board of Fire Underwriters, state and municipal building departments, and leading fire-insurance companies, he said, had adopted rules and regulations prescribing types of building materials, thickness of walls, permissible areas between fire cut-off walls, minimum distances between buildings, standard spacings for sprinkler heads, and other structural provisions for retarding the spread of fire. In most large cities, plans had to be submitted to the local building departments for approval before construction permits would be granted. In the suburbs and smaller towns, supervision of design was more frequently superficial, and the state or insurance-company recommendations might be the only regulating restrictions.

State departments of labor usually requested that plans of new industrial plants be submitted to them for approval as to the number and locations of fire towers and exits, sizes of door openings, spacing of fire cut-off walls, the regulations being more applicable to multiple- than single-story buildings. Municipal supervision of the design and construction of buildings had proved beneficial and effective in reducing the spread of fires. The gradual replacement of old, combustible-type buildings by fire-resisting structures was in many instances safeguarding adjoining property by the removal of fire hazards.

The low rates granted by insurance companies on buildings fully equipped with sprinkler protection had proved an effective incentive in having this automatic system quite generally installed where the contents were of a combustible nature. In mill buildings as well as steel-frame structures with wood roofs, sprinklers were widely used. In fire-resisting buildings, when the contents were non-combustible they were often omitted, but standpipes with fire hose might be provided. Portable fire extinguishers were likewise extensively distributed for emergency use.

It was the duty of industrial architects and engineers, said the author, to recommend to their clients the type of fire protection best suited to the local conditions and plant needs. In modern industrial plants of large size it was customary to provide in addition to automatic fire protection inside of buildings a yard hydrant system with fire plugs at strategic and suitable locations around the property. This underground pressure was preferably arranged in a loop system around main buildings or groups of buildings to insure ample pressure and safeguard against a water shortage in times of emergency. One or more fire pumps were provided as a reserve in case of city water pressure being low or the supply in auxiliary tanks or reservoir being insufficient.

In other words, modern industrial plants were to a large extent being designed and constructed of fireproof or slow-burning materials, supplemented by automatic and emergency fire protection where the character of the products made or the local conditions justified the investment in fire-fighting facilities. The insurance companies were usually successful in making the plant owner realize that even though the fire loss might be largely covered by insurance, the loss of production as a result of a fire would more than pay for the cost of reasonable fire protection.

WITH the growing use of material-handling equipment in manufacturing plants has arisen a demand for a closer knowledge of how to correctly apportion its charges to work. In 1924 a modified form of the machine-hour rate plan was developed and applied by the Mathews Conveyer Co., and has proved successful during the course of its two years' test.

In this plan the cost of installation was added to the purchasing price of each piece of equipment. Then a careful estimate was made of the probable life of each item. Upkeep and repairs and the small amount of power consumed by each, both over the period of assumed life, are included for convenience in the price of equipment. Rent, taxes, heat, light, supervision, and certain other items are not charged directly against the conveyor systems. These items have been calculated into a general hourly operating rate set up for the whole factory and applied as burden to the various departments.—*Manufacturing Industries*, March, 1926, pp. 169–170.

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[6] Treasurer, Bigelow, Kent, Willard & Co., Boston, Mass. Mem. A.S.M.E.
[7] Spicer Mfg. Corp., Plainfield, N. J. Mem. A.S.M.E.
[8] Deane Works, Worthington Pump & Machinery Corp., Holyoke, Mass. Mem. A.S.M.E.
[9] Harrisburg, Pa.
[10] Managing Editor, A.S.M.E., New York, N. Y. Assoc-Mem. A.S.M.E.

Design and Test of Susquehanna Station[1]

Details of Preliminary Studies Made in the Design of The Metropolitan Power Company's 30,000-Kw. Pulverized-Coal-Burning Power Plant at Middletown, Pa., Together with Data on Performance Obtained in Tests

By E. M. GILBERT,[2] READING, PA.

THE design of this station was carried out on a somewhat different plan from that usually followed. Instead of designing the plant almost entirely on the basis of the operating economy to be obtained from the apparatus installed, and merely watching the expenditure to be sure that it did not pass the point where the fixed charges would be considered excessive, a careful detailed study of the fixed charges as well as the economy of each piece of apparatus was made, with a very close examination into the increment cost. By this is meant, for instance, that when buying an economizer, instead of determining the size of economizer which would give, upon the whole, a return of, say, 17 per cent on the investment, an endeavor was made to see that the last 10 per cent of surface installed gave the return required on the investment, which meant that the average return on each piece of apparatus of this kind would of necessity be higher than that ordinarily figured.

In 1922, when this design was first started, the art of power-plant design had reached the stage where one of its periodic big steps forward was about to be taken. Many will remember how radically the design of plants changed when hand firing was superseded by stokers, and when turbines began to replace engines. In the same way, at this time there was a decided trend toward more efficient plants, with higher pressures and superheat. Feedwater is now being heated more generally by economizers and by means of steam bled from turbines. Pulverized fuel, while still in an experimental stage, is fast becoming a larger factor, and, in fact, many changes are in process of development which indicate a radical alteration in general design.

WATERSIDE VIEW OF SUSQUEHANNA STATION, MIDDLETOWN, PA.

In the ultimate analysis, a power plant is nothing more than a manufacturing concern which converts fuel into a commodity to be sold to the public. Of the materials which enter into its manufacture, fuel is by far the most important, the percentage of the fuel cost to the final cost, exclusive of fixed charges, varying from 60 to 80 per cent, while the labor and maintenance of the plant form the smaller percentage of the total. The fixed charges, however, are by far the most important factor of the whole business. Most any economically designed station, unless it has a very high-priced fuel or a very poor load factor, carries more than 50 per cent of the total expense of production under the heading of fixed charges, which includes depreciation, amortization, and taxes; and it must be remembered that these charges go on year after year, whether the plant is operating or not, and in many cases after the plant has been completely abandoned except for mere stand-by service.

STOKER OR PULVERIZED-FUEL FIRING

In determining what method of firing to use in this plant, particular stress was laid upon the fact that it was desired to obtain something which would render the plant as far as possible immune from the tremendous fluctuations in coal price which had existed for the past several years. At Middletown, river coal could be obtained direct from the river and fresh-mined anthracite and bituminous from the minimum-freight-rate zones, and, as they all came from different directions and different coal fields, if they all could be burned successfully a long step in the direction desired would be obtained. Incidentally, also, anthracite coal could be stored in immense quantities without danger of deterioration, and consequently could be purchased on the cheapest market available and held against emergency conditions. It was realized, of course, that pulverized fuel was more or less in an experimental stage, especially where anthracite was concerned, and a great deal of development would be required before it would be considered as having passed this stage. However, after carefully canvassing the market in all directions, it was decided to use this equipment in the plant, buying various types of the then existing apparatus for pulverizing each class of fuel, but building the furnace so that it would be designed primarily for its highest efficiency with bituminous coal. Incidentally, it is interesting to note that since the plant has been completed, all three grades of coal have been successfully burned, and that it has been found possible to obtain over 200 per cent of boiler rating with the anthracites. Anthracite and bituminous have also been mixed and burned successfully, but as yet no efficiency tests have been made on the former, although it is known from general operating results that when anthracite is burned the highest capacities on the boilers cannot be obtained, and the efficiencies are lower on the design of furnace employed than is the case with the bituminous only.

In considering the boilers for the station, a study was made in order to determine the most economical type and size to install, the most economical feedwater and flue-gas temperatures, and the economy to be obtained by the use of economizers.

In all this work the figures used covering price, efficiency, temperatures, etc. were obtained directly from the representatives of the manufacturers, and in many cases these representatives helped in the actual study. Different designs of the same type of apparatus were used in each case, seven makes of boilers being used in obtaining the curves following; in this paper, however, only one set of curves is shown.

Fig. 1 shows the estimated total yearly plant operating cost, including the fixed charges, in so far as it is affected by the boilers and economizers, plotted against the total investment necessary for boilers and economizers of various sizes for various stages of

[1] Designed and constructed by the W. S. Barstow Management Association.

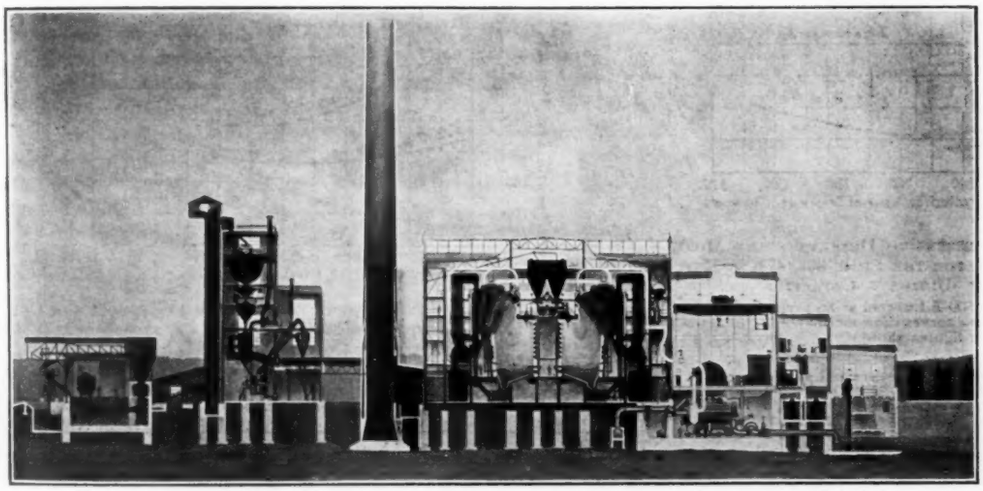
[2] Vice-President and Chief Engineer, W. S. Barstow Management Association, Metropolitan Edison Co. Mem. A.S.M.E.

Presented at a meeting of the Philadelphia Section of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, Philadelphia, Pa., November 24, 1925.

feedwater heating. This curve indicates that three-stage heating is the most economical where economizers are used in connection with stage feedwater heating by means of steam bled from the main turbine. On account of the slight difference in economy, as shown by the curves, between two-stage and three-stage heating, two-stage was selected because of the greater simplicity of its mechanical appliances and operation. The curves indicate also that where economizers are not considered, four-stage heating is justifiable. The figures on this and the following two curves are not actual costs or investment, but are relative and show the method only.

Fig. 2 shows the estimated yearly operating cost, with the fixed charges not included, plotted against the total investment for boilers and economizers. Contour lines are plotted on this curve which show the percentage return on increment investment for the various degrees of feed heating, and indicate between what limits additional investment for greater efficiency or lower operating cost will produce a given return on the additional investment necessary to attain this lower cost.

Fig. 3 shows the efficiency of the same size of boilers equipped with various sizes of economizers, plotted against the total cost of boilers and economizers. The curve indicates the high and low price for straight-tube boilers without economizers as well as the cost of bent- or curved-tube boilers, without and with varying quantity of economizer surface. It indicates that for the same amount of capital necessary to purchase the cheapest straight-tube boilers without economizers a much greater efficiency can be secured by purchasing bent-tube boilers with economizers. It indicates that where economizers are used a much less efficient and less expensive boiler can be justified, since efficiency in the boiler is not so important when economizers are used. As boilers of the bent-tube type are inherently cheaper than those of the straight-tube type, their use in combination with economizers is unquestionably most economical within certain pressure limits, even though they in themselves may be less efficient than the straight-tube type. This, of course, applies only below the safe working pressure for bent-tube boilers. Studies similar to the above were made on all sizes and types of boilers, as well as on all possible combinations of boilers and economizers.



CROSS-SECTIONAL VIEW OF SUSQUEHANNA STATION, MIDDLETOWN, PA.

A study was made in order to determine the difference in economy between the single-pass and the two-pass type of surface condensers, as well as the most economical quantity of condenser surface using circulating water velocities of from 5 to 10 ft. per sec. This study was based on a 27,500-kw. load on a 30,000-kw. unit, 280,000 lb. of steam condensed per hour, and considered the effect of vacuum on the operation of the main turbine and the extent to which this vacuum could be utilized. It considered also the average monthly circulating-water temperatures, pumping costs, initial cost of condenser, tube maintenance, etc., and was designed to indicate the most economical condenser.

Fig. 4 shows the yearly plant-operating cost, in so far as it is affected by the condenser, in thousands of dollars for various sizes of single-pass condenser with different velocities of circulating water.

From these studies and the equipment that was available at the time, it was decided to build the plant for an operating steam pressure of 350 lb., 680 deg. fahr. temperature, and an average vacuum of 29 in. It was decided to provide for bleeding the turbine at two stages for heating feedwater, and to provide a third bleed point on the turbine for the future installation of evaporators if found advisable. It was found that very good water could be obtained from a well at the station site, and an air intimate-contact vacuum heater was installed to remove the oxygen from the condensate and make-up water and to maintain a constant feedwater temperature, steam being supplied to it from the exhaust of the dual-driven equipment, operated by thermostatic control.

The principal equipment in the main part of the station consists of—

1—30,000-kw., 18,000-r.p.m., 17-stage General Electric Co. turbo-generator
1—45,000-sq. ft. single-pass condenser, Wheeler Condenser & Engineering Co.
4—1477-hp. Connelly boilers, Lopulco pulverized-fuel-burning equipment
2—7500-sq. ft. Sturtevant economizers
2—7700-sq. ft. Foster economizers.

The principal equipment in the coal-preparation plant consists of—

1—Hardinge mill
2—46-in. Fuller air mills
2—46-in. Raymond air mills
2—Wood steam and flue-gas driers
2—Randolph steam and flue-gas driers
2—Fuller-Kinyon pumps.

The mills are so arranged with individual bunkers and with a weigh larry to supply each bunker, that the actual amount of coal pulverized by any mill can be accurately determined.

This pulverizing plant has been called a museum because of the variety of machines which it contains, but the author is pleased to say that all of these machines have fulfilled their guarantees and all are working satisfactorily. The Hardinge mill was primarily installed to grind the harder grades of anthracite, the Fuller mills to grind the softer grades of anthracite and bituminous, and the Raymond mill to grind bituminous only. The Hardinge mill is provided with Wood driers and two mills are provided with Randolph driers, and two mills, one Raymond and one Fuller, operate without any driers.

From the data obtained during nine months of operation it has been concluded that bituminous coal containing not more than 4 per cent of moisture can be very satisfactorily ground at any time without drying, but that anthracite, in order to be pulverized satisfactorily, must be dried to from $1\frac{1}{2}$ to 2 per cent moisture content.

Fig. 5 shows the result obtained from the methods of construction and design that were employed. It will be noted that the costs have been figured both on the basis of considering the generating units as 30,000-kw. and on the basis of considering them 35,000-kw. The company believes that it has a 70,000-kw. plant, and it intends to operate it on that basis, and the manufacturers of the turbines say that this can be done satisfactorily. One machine has been operated for two or three hours at a stretch at over 35,000 kw. or 39,800 kva., and there has never been any difficulty with heating or with operation. This operation has been carried out under normal conditions and with one spare boiler out of service, so that the plant is fully designed for the 35,000-kw. rating. Naturally, the cost of the first unit was considerably greater than the cost of the completed plant, because with the first unit the complete boiler house, pulverizer house, coal-handling plant, coal bunkers, etc., for two units were installed and charged to one unit. Incidentally, sufficient

coal-drying and coal-pulverizing apparatus was also installed and has been in use. The second unit is not quite finished, but all contracts are in and the estimate of the completed plant has been very closely figured upon the basis of the costs obtained in installing the first unit.

TESTS OF STATION

During the first two weeks of July, 1925, three tests were made upon the Susquehanna Station. The first test, hereinafter designated as Test PT, was a preliminary one started on June 30 and continuing for 70.6 hr. This test was conducted under the supervision of the engineers of the Metropolitan Power Company and was observed by Mr. K. S. Wingfield, representing the firm of Murray & Flood.

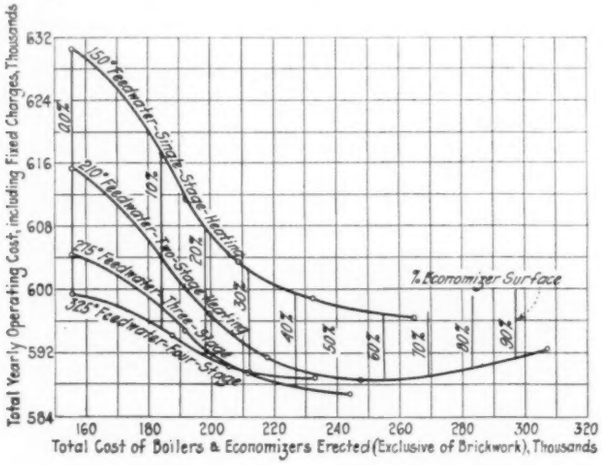


FIG. 1 STUDY OF BOILERS AND ECONOMIZERS TO DETERMINE THE MOST ECONOMICAL FEEDWATER TEMPERATURE FOR THE FIRST 30,000-KW. UNIT OF A PLANT OF 180,000 KW. ULTIMATE CAPACITY

(Based on 159,000,000 kw-hr. per year, 13,500-B.t.u. coal at $6 per ton, 1500-hp. boilers, and fixed charges at 17 per cent. These curves show method only, the actual investment being considerably less than the figures show.)

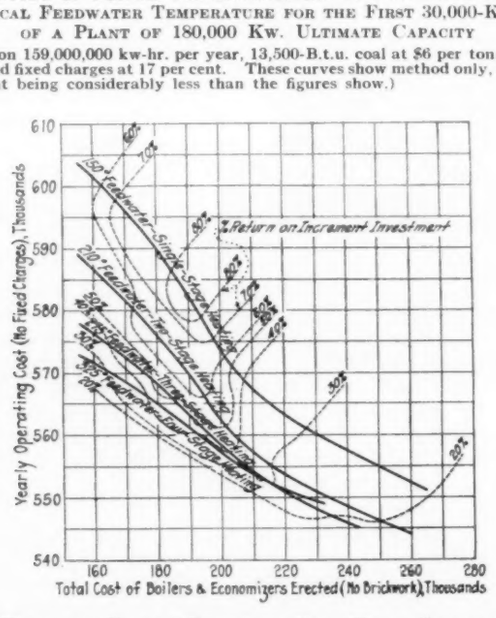


FIG. 2 ESTIMATED YEARLY OPERATING COST (FIXED CHARGES NOT INCLUDED) PLOTTED AGAINST TOTAL INVESTMENT FOR BOILERS AND ECONOMIZERS

(Based on 159,000,000 kw-hr. per year, 13,500-B.t.u. coal at $6 per ton, 1500-hp. boilers, and fixed charges at 17 per cent. These curves show method only, the actual investment being considerably less than the figures show.)

The second test, hereinafter designated as Test OT, was the official test conducted under the direct supervision of Murray & Flood. This test was of 72.2 hr. duration. The station was operated for both tests under conditions representative of normal operation for the time of year when made. An average plant output of 25,150 kw. was carried during the test, with a maximum hour of 35,453 kw. and a minimum hour of 18,227 kw. The maximum hour was attained under unfavorable conditions of excessively high circulating-water temperature and with the steam superheat ap-

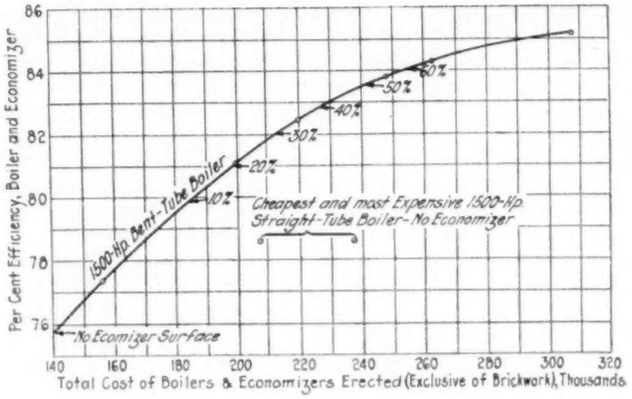


FIG. 3 EFFICIENCY OF BOILERS EQUIPPED WITH VARIOUS SIZES OF ECONOMIZERS PLOTTED AGAINST TOTAL COST OF BOILERS AND ECONOMIZERS

(Based on 19,5000,000 kw-hr. per year, 13,500-B.t.u. coal at $6 per ton, 212 deg. fahr. feedwater temperature, and two-stage heating. Efficiencies based on stoker operation. Curve shows method only, the actual investment being considerably less then the figures given.)

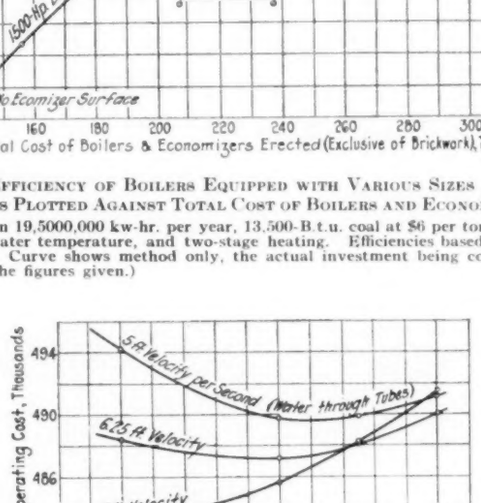


FIG. 4 YEARLY PLANT-OPERATING COST, IN SO FAR AS AFFECTED BY CONDENSER, FOR VARIOUS SIZES OF SINGLE-PASS CONDENSERS WITH DIFFERENT VELOCITIES OF CIRCULATING WATER

(Based on 27,500-kw. load on a 30,000-kw. turbo-generator, 250,000 lb. of steam condensed per hour, and 159,000,000 kw-hr. per year generated.)

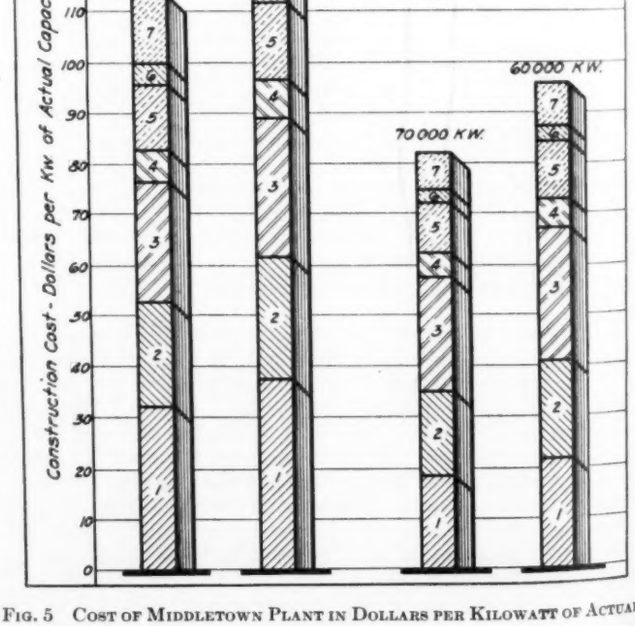


FIG. 5 COST OF MIDDLETOWN PLANT IN DOLLARS PER KILOWATT OF ACTUAL CAPACITY

proximately 10 per cent below that guaranteed by the equipment manufacturers.

The third test conducted, and hereinafter designated as Test ST, was started on July 10 and continued for 22.5 hr. This test was carried out under the supervision of Murray & Flood and was made to ascertain the efficiency of the boiler plant which might be realized under favorable conditions, and also to obtain an approximate check of the steam consumption of the turbine unit. For the purpose of this test, bleeding from the turbine was practically eliminated, resulting in water of a lower temperature being fed to the economizers than was the case in Test OT, and also resulting in the utilization of practically all of the superheated steam by the turbine in the production of energy.

Data Obtained During The Tests

Inasmuch as these tests were run to determine the plant efficiency, special pains were taken to see that no error occurred in weighing the coal or in measuring the kilowatt-hour output. All other figures, while very useful, were incidental. All coal was weighed in a large weigh larry that serves the raw-coal bunkers, each weight being checked by two men. This means that the results given are based on weight of coal actually paid for, and include all losses incidental to transporting and pulverizing.

The pulverized-coal bunkers were very carefully calibrated so that any variation at the beginning and end of the test could be noted and corrections made, if necessary.

All instruments, such as thermometers, calorimeters, scales, water meters, watt-hour meters, etc., were calibrated before and after each test, and, in fact, the water meters were calibrated several times during the test.

Every precaution was taken in obtaining the samples of coal from which the B.t.u. content was to be determined. After consultation with the Combustion Engineering Company and the Bureau of Mines, a man was stationed along the traveling belt which carries the raw coal from the cars to the bunkers, and shovelsful of coal were taken from this belt at regular intervals as it passed the operator. These samples were ground and subdivided in the usual way and put into airtight containers for analysis. The analysis, which is given in Table 1, was not only made by the company's own laboratory but by the Bureau of Mines and the Combustion Engineering Company. Samples of coal from pulverized-fuel bins and samples of ash from the ashpit and flue were also carefully obtained and analyzed.

Coal Preparation and Transportation

Table 2 gives the number of short tons of coal milled and also the energy required for handling, transporting, and feeding coal to the boilers. On the official test OT a total of 15.63 kw-hr. per short ton of coal was required for its preparation and handling, which amounts to 0.81 per cent of the plant output. In the design of the station, in making a comparison between the cost of operation with pulverized fuel and the cost of operation with stokers, a figure of 20 kw-hr. per ton was used.

The distribution of energy required for the preparation and transportation of coal during test OT was as follows:

	Kw-hr. per short ton of coal	Per cent of total energy	Per cent of plant output
Mills	10.06	64.2	0.520
Raw-coal handling	0.49	3.1	0.026
Coal transportation	1.21	7.7	0.062
Lighting and losses	2.84	18.4	0.149
Furnace feeders and prim. fans	1.03	6.6	0.053
Total energy for coal preparation and transportation	15.63	100.0	0.810

The results of nine months' run on this plant indicate that the kilowatt-hours used for grinding per short ton depend almost entirely upon the coal being ground. Sterling coal is very friable. Some of the other bituminous coals are harder and take more energy, and with the anthracite coal nearly double the amount of energy is required.

It is interesting to note the results for the past five months. In June, 17.1 kw-hr. were used for grinding coal; in July, 14.9; in August, 16.5; in September, when a good deal of hard coal was used, 18.2; and in October, 16.4.

TABLE 1 CHARACTERISTICS OF COAL USED DURING TEST

Coal	Test OT	Test ST
Kind used	Bituminous	Bituminous
Mine	Sterling	Sterling
Ultimate Analysis, Raw Coal, Dry Basis:		
Carbon, per cent	82.73	
Hydrogen, per cent	4.71	
Nitrogen, per cent	1.63	
Sulphur, per cent	1.55	
Oxygen, per cent	3.13	
Ash, per cent	6.25	
Proximate Analysis, Raw Coal as Received:		
Moisture, per cent	2.47	2.23
Volatile matter, per cent	23.58	23.62
Fixed carbon, per cent	67.85	67.97
Ash, per cent	6.08	6.18
Sulphur, per cent	1.46	1.54
Heating value per lb., B.t.u.	14,324	14,385
Fineness of Pulverized Fuel:		
On 100-mesh screen, per cent	9.43	8.5
On 140-mesh screen, per cent	6.47	6.5
On 200-mesh screen, per cent	8.20	8.0
Through 200-mesh screen, per cent	75.90	77.0
Ash		
Combustible in ash from ashpit, per cent	0.0	
Combustible in flue dust from economizers, per cent	36.7	41.0
Combustible in flue dust from soot hoppers, per cent	34.8	

TABLE 2 PREPARATION AND TRANSPORTATION OF COAL

	Test OT	Test ST
Total coal transported and milled, net tons	1008.4	262.9
Coal milled per hour, average, net tons	10.8	11.7
Energy per ton of coal milled, average kw-hr.	10.06	9.89
Energy for raw-coal handling, kw-hr.:		
Total	489	163
Per net ton of coal	0.49	0.62
Energy for coal transportation, kw-hr.:		
Total	1.224	408
Per net ton of coal	1.21	1.56
Energy for lighting and losses, kw-hr.:		
Total	2,864	457
Per net ton of coal	2.84	1.74
Total energy for preparation and transportation, kw-hr.:		
Total	14,715	3,630
Per net ton of coal	14.60	13.81
Energy for furnace coal feeders, kw-hr.:		
Total	1,044	252
Per net ton of coal	1.03	0.96

TABLE 3 PERFORMANCE OF BOILER PLANT

	Test OT	Test ST
Total Quantities		
Duration of test, hr.	72,167	22,517
Water fed to boiler plant, lb.	22,658,753	5,820,090
Saturated steam generated, lb.	665,853	161,490
Superheated steam generated, lb.	21,744,000	5,587,800
Make-up, lb.	248,900	70,800
Coal burned in furnaces, lb.	2,016,294	524,115
Average Pressures		
Steam, No. 3 drum outlets, lb. per sq. in.	349.1	347.5
Air, primary air to furnaces, inches of water	15.1	14.9
Average Drafts, Inches of Water		
In furnaces	0.03	0.005
In 4th pass of boiler	0.76	0.38
At economizer outlets	2.2	1.2
At fan inlets	9.3	5.6
Average Temperatures, Deg. Fahr.		
Steam saturated	435.5	435.8
Steam superheated	629.9	630.0
Steam superheat	194.4	194.2
Water, to boiler-feed pump	211.5	147.5
Water, economizer outlets	295.3	238.5
Gases, in 4th pass of boiler	584.3	553.1
Gases, economizer outlets	316.3	245.2
Products of Combustion		
At boiler outlets CO_2, per cent	14.5	15.6
At boiler outlets CO, per cent	0.0	0.0
At boiler outlets O, per cent	4.5	3.2
Dry gases per lb. coal, lb.	14.11	13.23
Hourly Quantities		
Coal burned in furnaces, lb.	27,950	23,250
Coal burned per burner, lb.	1,551	1,292
Actual water, lb.	314,000	258,500
Actual water per lb. of coal, lb.	11.25	11.11
Factor of evaporation	1.087	1.144
Equivalent evaporation, lb.	342,000	296,000
Equivalent evaporation per lb. of coal, lb.	12.22	12.72
Average boiler hp. developed, boiler & superhtr.	9,920	8,580
Per cent builders' rating, boiler and superheater	224	194
Efficiencies		
Boilers and superheaters, per cent	82.9	85.8
Boiler plant, per cent	89.4	92.9

Performance of the Boiler Plant

The performance of the boiler plant during tests OT and ST is stated in detail in Table 3.

Under normal operating conditions the boiler plant should deliver superheated steam at 350 lb. pressure and 220 deg. of superheat. The pressure condition during the test was practically met, but the superheaters failed to come up to guarantees and the temperature of the steam delivered from the superheaters was less than that stated in the guarantee. This condition has since been reme-

died, so that the steam temperature is now equal to or higher than the guaranteed temperature.

The quality of steam delivered to the superheaters is the average of that determined from three calorimeters.

The sixth item of Table 3, which records the coal burned in the furnace, is in fact the coal delivered to the raw-coal bunkers, and therefore all losses of coal due to pulverizing and to transportation have been charged against the boiler plant, leaving the results of the test resting upon the coal actually paid for rather than that actually burned.

During the course of test OT the boilers were operated through a range of from 174 per cent of rating during the minimum hour's output of 16,100 kw. on July 8 from 5:00 to 6:00 p.m., to a maximum of 288 per cent of rating during the maximum hour's output of 33,400 kw. on July 10 between 9:00 and 10:00 a.m., with an average of 224 per cent for the entire test. The variations in the principal pressures, temperatures, and quantities over this range during test OT, were as follows:

	Maximum	Average	Minimum
Per cent builders' rating	288	224	174
Plant output in kw	33,400	25,100	16,100
Temperature of gases, deg. fahr.:			
(*a*) 4th pass of boilers		584.3	
(*b*) Inlet to economizers		568.4	
(*c*) Outlet of economizers		316.3	
(*d*) Drop in economizers		252.1	
Water temperatures, deg. fahr.:			
(*a*) At inlet of economizers		212.2	
(*b*) At outlet of economizers		295.3	
(*c*) Rise in economizers		83.1	
Superheat in deg. fahr		194.4	
Steam-pressure drop through superheaters, lb. per sq. in.		7.8	
Steam-pressure drop between superheaters and turbine nozzle, lb. per sq. in.		14.0	

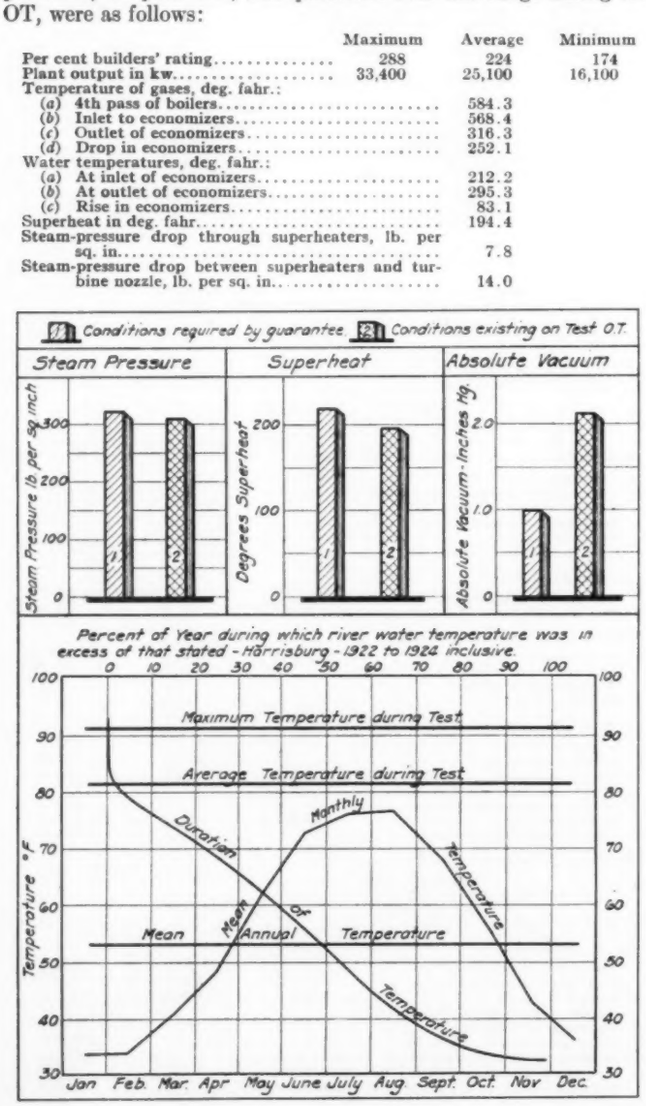

Conditions required by guarantee
Conditions existing on Test O.T.
Steam Pressure
Superheat
Absolute Vacuum
Steam Pressure lb. per sq. inch
Degrees Superheat
Absolute Vacuum - inches Hg.
Percent of Year during which river water temperature was in excess of that stated - Harrisburg - 1922 to 1924 inclusive.
Maximum Temperature during Test
Average Temperature during Test
Duration
Monthly
Mean Annual Temperature
Temperature °F
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec

FIG. 6 CONDITIONS EXISTING DURING OFFICIAL TEST COMPARED TO THOSE REQUIRED BY GUARANTEES

On test ST the loading of the boilers was kept much more constant, varying between a minimum of 187 per cent during the hour of minimum output and a maximum of 204 per cent during the hour of maximum output.

PERFORMANCE OF THE MAIN TURBINE GENERATOR

The performance of the main turbine generator is stated in detail for tests OT and ST in Table 4.

The average generation during test OT was 26,790 kw., and the variation in load was between a maximum of 35,453 kw. and a minimum of 18,227 kw.

The turbine with its condenser operated under unfavorable conditions in that the superheat at the turbine throttle averaged on test OT 197.6 deg. as against 220 deg. specified in the guarantees. Furthermore the inlet circulating water had an average temperature of 82.6 deg., which high temperature should be present for only approximately two per cent of the time during a year's operation.

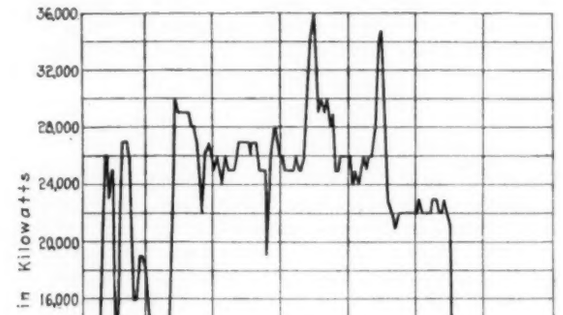


FIG. 7 WEEKLY LOAD CURVE FOR TEST PERIOD JULY 6 TO JULY 12, 1925; SUSQUEHANNA STATION, METROPOLITAN POWER CO.

(See Fig. 6.) As a matter of fact, the circulating-water temperature on July 7 went as high as 91.5 deg.

Otherwise during test OT the plant was run under normal operating conditions, and approximately 10.84 per cent of the total superheated steam supplied to the turbine was bled to the stage heaters or was supplied to the turbine glands. During test ST, however, the stage heaters were practically cut out of service, with the result that only 3.8 per cent of the superheated steam supplied to the turbine was bled to the stage heaters or supplied to the glands.

The total water rate of the turbine, as stated in the table, shows consistent results for both test OT and test ST. The net water rate of the turbine likewise shows results which are consistent and are to be expected when a decrease of load shows an increased water rate during test ST.

As has been previously stated, the turbine operated under a low superheat and a high-temperature inlet circulating water. As these do not represent average conditions, the superheat already

TABLE 4 PERFORMANCE OF MAIN TURBINE GENERATOR

	Test OT	Test ST
Quantities		
Duration of test, hr	72,167	22,517
Energy generated, kw-hr	1,932,294	499,096
Voltage, generator leads, volts	13,800	13,820
Power factor calculated, per cent	91.9	87.6
Steam Pressures		
Turbine throttle, lb. per sq. in.	318.5	323.3
Turbine, primary nozzle, lb. per sq. in.	306.1	272.8
Turbine, secondary nozzle, lb. per sq. in.	200.5	155.7
Steam Temperatures		
At turbine throttle, deg. fahr.	624.8	625.6
Superheat, deg. fahr.	197.6	197.1
Hourly Quantities		
Energy generated, kw-hr	26,790	22,200
Steam to turbine, lb.	300,000	247,500
Condensate from condenser, lb.	268,000	238,200
Total water rate of turbine, lb. per kw-hr.	11.20	11.15
Water rate of turbine less bleeding of glands, lb. per kw-hr.	9.97	10.73
Total steam to turbine corrected for vacuum, pressure, and superheat variations from those stipulated, lb.	273,500	228,000
Corrected total water rate, lb. per kw-hr.	10.20	10.25
Corrected net water rate, lb. per kw-hr.		9.85
Guaranteed water rate, lb. per kw-hr.	9.93	10.12
Efficiency		
Thermal, per cent	24.2	24.3

having been corrected on part of the boilers and the water temperature having been above normal for only slightly over a week, it was considered necessary to correct the results obtained to actually see what the plant could do. Correction for the deviations of vacuum, pressure, and superheat from those specified for the guaranteed or normal operating conditions, of 1 in. absolute vacuum, 350 lb. pressure, and 220 deg. superheat, shows on test ST, during which the bleeding was practically eliminated, that the corrected net water rate, including steam fed to glands, would be approximately 9.96 lb. per kw-hr. generated, as against the guaranteed water rate for these conditions, of 10.12 lb. per kw-hr. It is indicated by this that the turbine bettered its guaranteed performance by approximately 1.58 per cent.

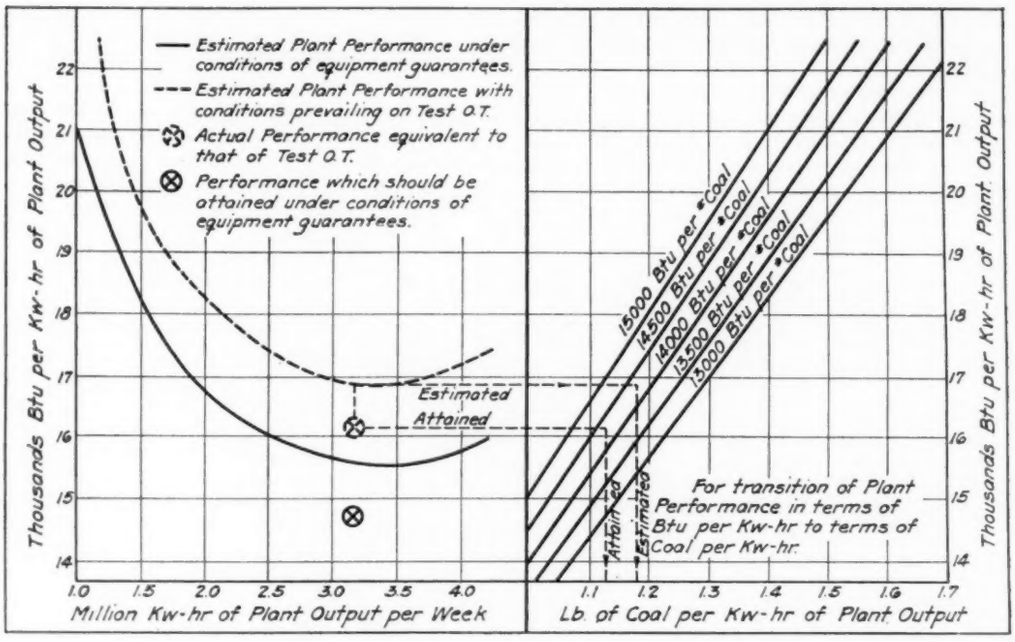

Estimated Plant Performance under conditions of equipment guarantees.
Estimated Plant Performance with conditions prevailing on Test O.T.
Actual Performance equivalent to that of Test O.T.
Performance which should be attained under conditions of equipment guarantees.
Estimated
Attained
Thousands Btu per Kw-hr of Plant Output
Million Kw-hr of Plant Output per Week
15000 Btu per Coal
14500 Btu per Coal
14000 Btu per Coal
13500 Btu per Coal
13000 Btu per Coal
Attained
Estimated
For transition of Plant Performance in terms of Btu per Kw-hr to terms of Coal per Kw-hr.
Lb. of Coal per Kw-hr of Plant Output

FIG. 9 COMPARISON OF WEEKLY PLANT PERFORMANCE ATTAINED DURING TEST OT TO THE ESTIMATED PERFORMANCE OF THE DESIGNS OF THE PLANT

The turbine generator was purchased from the General Electric Company with a stated capacity of 30,000 kw. at 80 per cent power factor, equivalent to 37,500 kva. During test OT the turbine was loaded up for a period of two hours and ten minutes on July 9, and for a period of one hour on July 10, in order to determine its capacity and the heating which occurred with that capacity. On July 9, during the two-hour period, the load varied between 34,500 kw. and 35,500 kw. with a maximum hour's generation of 35,453 kw-hr. On July 10 the output for the hour during which the capacity run was made was 34,500 kw-hr., and with a corresponding power factor of approximately 89 per cent imposing a load of 39,800 kva. upon the generator which was in excess of the 37,500 kva. specified within the guarantees.

Under these conditions the maximum temperature shown by the thermocouples located within the armature coils was 76 deg. cent. on July 9 and 77 deg. cent. on July 10. The temperature rise above that of the intake air to the turbine was 51 deg. cent. on July 9 and 50 deg. cent. on July 10, as against the 60-deg. cent. rise allowed within the specifications.

TABLE 5 CONDENSER PERFORMANCE

	Test OT	Test ST
Pressures		
Barometer, in. Hg	29.87	29.79
Vacuum (by mercury column), in. Hg	27.75	27.86
Pressure, absolute, in. Hg	2.12	1.93
Water Temperatures		
Circulating inlet, deg. fahr.	82.6	81.6
Circulating discharge, deg. fahr.	91.3	89.0
Condensate, deg. fahr.	100.5	96.4
Results		
Steam condensed per hr., lb.	268,000	238,200
Quantity of condensing water per hr. (c), lb.	31,900,000	33,450,000
Quantity of condensing water (c), gal. per min.	63,800	66,800
Heat transfer per deg. diff. temp. per sq. ft. per hr., B.t.u. per hr.	483	491

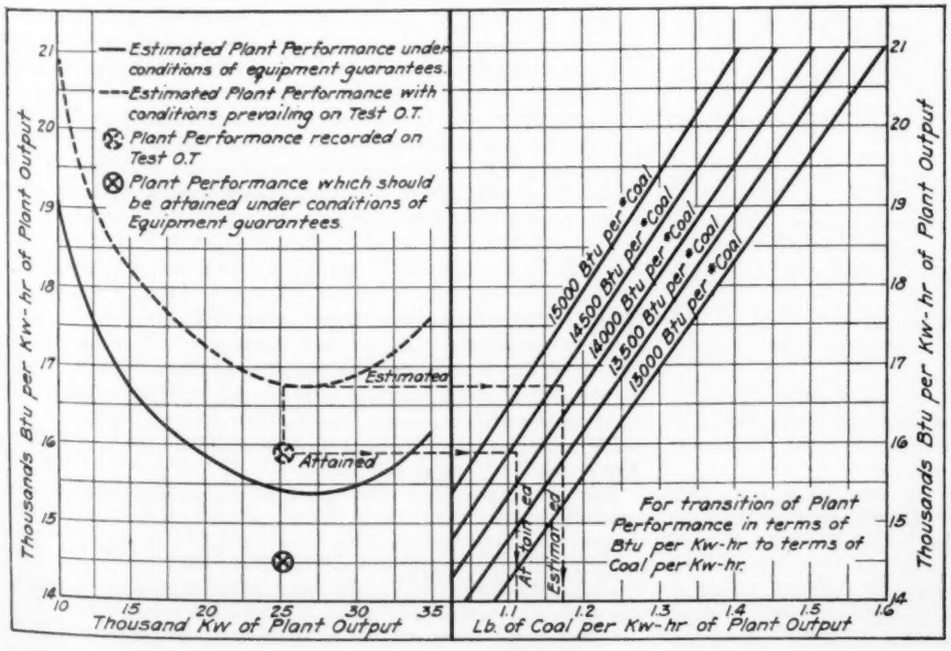

Estimated Plant Performance under conditions of equipment guarantees.
Estimated Plant Performance with conditions prevailing on Test O.T.
Plant Performance recorded on Test O.T.
Plant Performance which should be attained under conditions of Equipment guarantees.
Estimated
Attained
Thousands Btu per Kw-hr of Plant Output
Thousand Kw of Plant Output
15000 Btu per Coal
14500 Btu per Coal
14000 Btu per Coal
13500 Btu per Coal
13000 Btu per Coal
Attained
Estimated
For transition of Plant Performance in terms of Btu per Kw-hr to terms of Coal per Kw-hr.
Lb. of Coal per Kw-hr of Plant Output

FIG. 8 COMPARISON OF THE PLANT PERFORMANCE RECORDED ON TEST OT TO THAT ESTIMATED IN THE DESIGN OF THE PLANT

From the results obtained it appears that the plant can be rated at 35,000 kw. at 80 per cent power factor.

CONDENSER PERFORMANCE

The performance of the condenser is stated in detail in Table 5.

The condenser operated during both the official test and test ST under unfavorable conditions, inasmuch as the temperature of the inlet circulating water averaged 82.6 deg. fahr. during test OT and 81.6 deg. during test ST. In fact, the temperature of the inlet circulating water during test OT reached a maximum of 91.5 deg. As has previously been shown, the inlet circulating-water temperature prevailing during test OT and test ST should not in an average year be present for more than two per cent of the time, or approximately seven days. Fig. 6 shows the duration of river-water temperatures for the years 1922 to 1924, inclusive.

The amount of steam condensed per hour during the official test

was slightly lower than the maximum upon which the condenser guarantees were based, averaging 268,000 lb. per hour as against 280,000 lb. The amount of circulating water computed by the temperature-rise method, averaged during the official test approximately 63,800 gal. per min. against the 65,000 gal. stated within the guarantees as required to condense 280,000 lb. of steam per hour.

The heat transfer per degree difference of temperature per square foot of surface per hour, averaged 483 B.t.u. as against the 450 B.t.u. stated within the guarantees.

TOTAL PLANT RESULTS

The performance of the plant as a whole is stated in detail in Table 6.

In the official test the plant produced a kilowatt-hour of output for 1.11 lb. of coal, while under test ST, 1.121 lb. of coal was required.

The results achieved during these tests were excellent when it is considered that the plant operated with an inlet circulating-water temperature which was excessively high, and also that steam was furnished to the turbine at a superheat of more than 10 per cent below that called for by the guarantees.

If the deviations from specified vacuum, pressure, and superheat under which the turbine was guaranteed were corrected for, the coal rate of the Susquehanna Station during test OT would have been reduced from 1.11 lb. of coal to 1.013 lb. of coal per kw-hr. of output and the B.t.u. per kw-hr. would have been reduced from 15,900 to 14,510. Correspondingly, on test ST the pounds of coal per kw-hr. of plant output would have been reduced from 1.121 to 1.032 and the B.t.u. per kw-hr. of plant output from 16,100 to 14,850.

TABLE 6 GENERAL PLANT DATA AND RESULTS

	Test OT	Test ST
Duration of test, hr	72.167	22.517
Kw-hr. generated	1,932,294	499,096
Kr-hr. output	1,815,861	467,506
Kw-hr. to auxiliaries	116,884	32,488
Kw-hr. to coal house	14,715	3,630
Coal consumed, lb.	2,016,292	524,115
Total water evaporated, lb.	22,658,753	5,820,090
Average kw. generated	26,790	22,200
Average kw. output	25,150	20,800
Volts, generator leads	13,800	13,820
Current per phase, amperes	1,220	1,060
Average power factor—computed, per cent	91.9	78.5
B.t.u. per lb. coal	14,324	14,385
Deviation from specified vacuum, pressure and superheat in turbine guarantee, per cent	−8.9	−7.8
As Recorded by Test:		
Lb. coal per kw-hr. generated	1.042	1.051
Lb. coal per kw-hr. output	1.110	1.121
B.t.u. per kw-hr. output	15,900	16,100
Water evaporated per lb. coal, lb.	11.25	11.11
Efficiency of boiler plant, per cent	89.4	92.9
Water used per kw-hr. output, lb.	12.50	12.45
Per cent auxiliaries to plant output	6.43	6.94
Per cent coal-house energy to plant output	0.81	0.78
Per cent saturated to total steam	2.94	2.78
Per cent make-up to total steam	1.10	1.22
Corrected for Deviation of Vacuum, Pressure, and Superheat from Turbine Guarantees:		
Water used per kw-hr. output, lb.	11.40	11.49
Coal per kw-hr. output, lb.	1.013	1.032
B.t.u. per kw-hr. output	14,510	14,850

It is to be noted that while a boiler-plant efficiency of 92.9 per cent was attained on test ST as against 89.4 per cent on test OT, the total fuel consumption per kilowatt-hour of plant output on test ST was 2.42 per cent greater than that of test OT. This result justifies the installation of the bleeder heating system for feedwater provided by the designers.

Fig. 7 shows the load on the plant during the week of the test and Figs. 8 and 9 show test performance plotted against the designer's expected results.

After checking each individual piece of equipment it was found that certain equipment exceeded manufacturer's guarantees, and this is the reason that the operating results are better than those expected by the designers.

The operating figures for the past nine months during which the plant has been in operation, show that the plant performance every month has been better than the anticipated performance. Since the Sunday and night load is carried by hydro power, the plant is shut down at noon every Saturday and started again every Monday morning and the boilers are banked at night. Under these conditions the actual B.t.u. per kilowatt-hour output per month has varied from 17,600 B.t.u. per month with a 33 per cent load factor to 6,500 B.t.u. per month with approximately 60 per cent load fact or.

Discussion

IN THE discussion following the presentation of the paper, N. G. Reinecker[3] called attention to the great detail into which the author had gone, especially as regarded fuels. He knew of no plant doing better than the one described—running with 80 to 90 per cent monthly load factors, approximately 15,000 B.t.u. per kw-hr.

The author, amplifying his statements in regard to fuel, said that the cheapest coal was the most expensive. The company had tested many kinds of anthracite, and bituminous coal. 30,000 tons of coal had been taken from the river and stored in the yard. They had as yet made no official test which gave them definite figures on anthracite. The efficiency with bituminous was 85 per cent; with anthracite it was probably between 75 and 80 per cent. In preparing anthracite it was necessary to pulverize it to a fine degree to get results. There was difficulty in lighting anthracite also, as they had to use a big kerosene torch.

In reply to a number of questions asked by N. E. Funk,[4] the author said the brickwork actually cost as much as the boiler, the boiler being set 35 ft. in the air, with brickwork all the way round. Instead of running any tunnels out into the river, the plant was set back about 300 ft. from the river and the river brought directly past the condensers. With bituminous coal it was possible to run the boiler on a very low capacity. With anthracite it was impossible to run at low capacity without the burners going out. As to mixtures, the plant took coal out of the river which was delivered at $1.20 per ton, and could mix coals in any proportions with their arrangement of mills. If they had 30 per cent of bituminous they could burn any grade of anthracite.

Mr. Funk pointed out that one thing that was overlooked a great many times was the cycle which the plant must perform. In many cases plants were installed in two units with sufficient boilers to operate one. In other cases boiler plants were put in that were designed to operate for a short time only at the maximum capacity. Plants like the Susquehanna Plant sold all their power in bulk, whereas other plants had to distribute at a lower voltage.

Alfred Iddles[5] said that the stoker-fired plant fell down to the extent of about 3 per cent in efficiency, being handicapped to this extent by reason of the carbon put into the ashpit. A stoker-fired plant also failed when the CO_2 was run up, the carbon in the ash was run up also. It would run up very materially higher than the heat balance in the ash. When carbon in the ash was run up, the CO_2 was down around 11 and $11\frac{1}{2}$ per cent, and consequently about $2\frac{1}{2}$ per cent more than in the pulverized-coal plant. It would be interesting to know if the author could operate at 325 per cent continually and maintain the CO_2 at the ordinary figure.

Replying to Mr. Iddles, the author stated that it had been found possible to maintain continously over 290 per cent of rating with $14\frac{1}{2}$ per cent CO_2, and that the indications were that the company would be able to increase this with the aid of water-cooled furnaces.

Henry Kreisinger,[6] who concluded the discussion, said that powdered coal was able to stand on its own feet and did not need the nursing that it had needed three years ago, and that the author had given figures showing that a powdered-coal plant could be built as cheaply as a stoker plant.

Errata

PAGE 224, March issue: For "convex" at end of first line of note preceeding Par. 8, read "concave." In the bottom sketch of Fig. 9, change thickness of head from $\frac{7}{8}$ in. to $\frac{3}{4}$ in. In the sketch of the junction of head and shell above and to the right of the first-mentioned sketch, both plates should be $\frac{3}{4}$ in. thick, and the reinforcement at the bottom should be $\frac{3}{32}$ in. as at the top, instead of $\frac{1}{8}$ in. as shown.

Page 291, March issue: For "per cent" in last line of first column, read "deg. fahr."

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[4] Operating Engineer, Philadelphia Electric Co., Philadelphia, Pa. Mem. A.S.M.E.

[5] Chief Power Engineer, Day & Zimmerman, Inc., Philadelphia, Pa. Mem. A.S.M.E.

[6] Research Engineer, Combustion Engineering Corporation, New York, N. Y. Mem. A.S.M.E.

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

The Trend of Steam-Power-Plant Development

A CONCISE statement of the progress made in the past decade, so remarkable for the developments that have taken place within it in improving the economy of steam power plants, particularly large central stations. The essential conclusion to which the author comes is that while enormous gains have been made already and further gains are still possible, other factors which have increased in relative importance, particularly increase in fixed charges, may delay any further considerable decrease in coal consumption.

Load factor has a great influence on steam-station design. The influence on costs of daily, monthly, or annual load factors may be stated briefly as follows: (*a*) Daily load factor and the form of load curve affect fuel costs; (*b*) monthly load factor affects labor and fuel costs; (*c*) annual load factor affects fixed charges.

High annual load factors will warrant considerable refinement and higher investment costs to secure increased station economy. On the other hand, extremely low annual load factors warrant only a low-cost station because fixed charges constitute a larger item in power costs while fuel costs in such cases are relatively lower. Much special equipment has been installed the use of which was not economically justified by the actual operating life of that part of the plant. The relation of load factor to plant design is now better understood, and fewer mistakes are made than in earlier designs.

Cost of power consists of fuel maintenance, operating labor, and fixed charges. Fixed charges appear to be almost double fuel costs per unit of output. Hence the foremost problem confronting designers today is the reduction of initial investment in the plant.

Theoretical Factors in Station Design

Design and selection of steam-station equipment are governed by two factors which have been most effective in securing high efficiency. These factors are the utilization of the available heat head, and the heat balance. The main turbines are the most efficient elements in a central station. If heat head alone were considered, then all energy transformations should take place in them and all auxiliaries should be driven by electric power from the main generators. In practice this ideal is modified by such considerations as first cost, increasing efficiency of small steam turbines, reliability against shutdown, and space requirements.

Heat balance is more comprehensive than heat-head utilization. It implies a study of the plant design as a whole so that the greatest economical amount of heat energy in the coal may be delivered as electric power to the feeders leaving the station. Due regard must be given to the cost of obtaining such performance, and all gains must be balanced against the increased cost of securing such improvements. Heat-balance studies have resulted in the use of higher steam pressures and temperatures, reheating of steam, powdered coal, air preheaters, bleeder heaters for feedwater evaporators, and the various systems of electric drives for auxiliaries.

Steam Pressures and Temperatures

Of late, rapid advances have been made in increasing working steam pressures and they have reached 1200 lb. in a boiler of conventional type in this country and 3200 lb. in an experimental boiler in England. Steam temperatures, however, have increased only to 750 deg. fahr. For several years the author has urged the desirability of increased steam temperature, and he demonstrated the economic possibilities of higher temperatures in a recent paper.[1] Increased steam temperature involves increased expense only in the superheater, the main steam header and valves, and in the first stages of the turbine. Higher boiler pressure requires increased expense for all equipment from the boiler-feed pump practically to the turbine exhaust. On the other hand, steam consumption will be decreased by either higher steam pressure or higher temperature, and smaller pumps, boilers, superheaters, piping, and condenser equipment will be required. At the present time power-plant designers look to the metallurgists to develop steels suited for higher temperatures than 750 deg. fahr. In the meantime the general tendency is toward higher pressures, although eventually higher temperatures than 750 deg. fahr. will also be used.

[1] Higher Pressures or Higher Temperatures, A. C. Christie and D. C. Turnbull, Jr. Report of Prime Movers Committee, N.E.L.A., on Higher Steam Pressures and Temperatures, July, 1925.

Structural Features of Design

Building and foundations may account for one-fifth to one-third or more of the total cost of the plant, and they are more controllable on a given site with given requirements than steam or electrical equipment. Many variables, such as amount and topography of available ground, soil and flood conditions, circulating-water supply and levels, rail service, etc., are encountered with every power-house site. It is seldom, if ever, possible to build from the same design two power plants in different locations. Skilful arrangement of equipment is necessary to reduce building costs in any large measure.

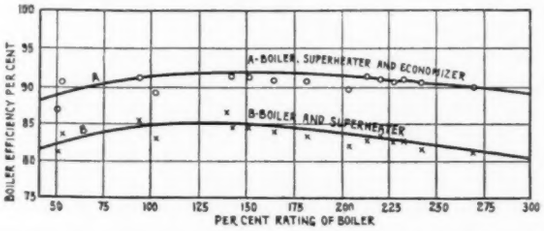


FIG. 1 TEST EFFICIENCIES OF 30,600-SQ. FT. BOILER, LAKE SHORE STATION, CLEVELAND ELECTRIC ILLUMINATING CO.

Volume is the more generally accepted unit for the comparison of plant designs. Considering boiler plants as now built, there appear to be possibilities of further developments in design and of reduction in total volume and cost of the structures. Turbine-room height and width are fixed by the requirements of the condenser and its auxiliaries, and by the clearances necessary to lift covers and remove rotors from turbines and generators. It has been suggested that vertical condensers would permit reductions in roof height and lessen turbine-room volume. Much of the electrical equipment formerly housed inside the building is now placed outside, and this has decreased building expense. The trend now is toward simple, plain, low-cost designs, and in some cases reinforced concrete has been used in place of structural steel and brick. Much money may be needlessly spent on the station structure, and careful study of this feature can often effect large savings in total plant cost.

Modern Boiler Plants

Modern boiler plants have four outstanding characteristics: namely, increased boiler size, high ratings in operation, new furnace designs, and automatic control.

Increased boiler ratings are now possible through improved furnace designs which produce higher efficiency over a wide range of load. Combined boiler, superheater, and economizer efficiencies, as found by tests on a 30,000-sq. ft. boiler at Lake Shore Station, are shown in Fig. 1. This curve is remarkably flat over

a wide range of load. Few boilers are now operated continuously at ratings above 300 per cent. Air preheaters tend to flatten the boiler-efficiency curve so that operation at peak load at much higher boiler ratings than 300 per cent does not require much sacrifice in fuel economy.

The cost of furnace and setting, air preheater, and forced- and induced-draft fans will be increased when high ratings must be carried, but these increased auxiliary costs are small compared with the costs of complete additional boiler plant. High boiler ratings tend, therefore, to lower the first cost, and are often justified on this basis for the given load conditions. These higher ratings are possible only with improved furnace designs.

In this connection the author briefly discusses the relative advantages of pulverized-coal systems and stokers, and points out generally the factors which warranted the installation of the former. Powdered coal brought about important changes in furnace design, in particular, the substitution for solid walls of air-cooled brick side walls and water-cooled walls. The combination of water-cooled furnace walls and air preheaters seems in practice to offer the most economical arrangement. Future designs of boilers may be built around the furnaces rather than entirely above them.

Steam Stations for Industrial Plants

The preceding discussion refers specifically to large central stations. Many industrial plants require a steam station to furnish steam for heating or process work or for power. The use factor of such equipment may be quite high, in which case refinements in design would be warranted that could not be justified with a low use factor.

While the same general tendencies prevail in industrial-plant design as in central stations, the former lags behind, due partly to the fact that the industrial steam plant is a secondary part of the whole works, and partly because less efficient operating management and personnel are available in the small plant than in the large electric works. Increasing boiler pressures, larger boilers of the water-tube type, pulverized coal or more modern stoker equipment, and large condensing or non-condensing steam turbines now characterize the equipment of the larger industrial plants. There appears to be a tendency in European industrial plants where process steam is required to use even higher steam pressures than in central-station practice.

Small plants are usually built with little or no thought given to fuel economy. Owners would save money by engaging competent engineering advice before building such small plants.

In the new boiler plant of a Canadian paper company, the Lopulco pulverized-coal-firing system will be installed, with a central pulverizing plant using steam driers and located near the wharf some 1200 ft. away from the boilers. This plant is designed to burn any available coal, including Nova Scotia coals with low-fusing ash. An addition to the boiler room of another Canadian industrial plant consists of a 700-hp. boiler to be initially operated at 130 lb. gage pressure but built for 350 lb. gage. A superheater to provide 100 deg. fahr. steam temperature will be added later. A Fuller-Bonnot unit pulverizer will furnish powdered coal to the solid-wall combustion chamber. Secondary air will be admitted through a hollow bridgewall. No water screens will be used on this plant. The unit will operate at 250 per cent rating with peaks up to 300 per cent. An old economizer now in place will be used to heat the feedwater.

The recent development of high-pressure accumulators has directed the attention of engineers to the possibilities of this equipment. In large central stations the principle of conservation of heat head, together with the flat boiler-efficiency curve over wide ranges of load, does not leave much opportunity for accumulators to effect savings. Another situation prevails in the process work of industrial plants, particularly where widely fluctuating steam demands are common. Heat head is then of less importance than heat capacity. [Paper presented Jan. 28, 1926, by A. G. Christie (Mem. A.S.M.E.), Professor of Mechanical Engineering, Johns Hopkins University, Baltimore, Md., at the annual meeting of the Engineering Institute of Canada, Toronto, Ont.; abstracted through *Power Plant Engineering*, vol. 30, no. 4, Feb. 15, 1926, pp. 258–262, 6 figs., *g4*]

Short Abstracts of the Month

AERONAUTICS

The Albatros Flying Boat on Wheels

Description of a two-seater light plane of German manufacture with a fuselage of mixed construction and with a wing area arranged in the form of a biplane with the lower plane considerably smaller than the top plane in both span and chord. To give the two occupants as good view as possible, the two main planes have been very heavily staggered in relation to one another. The machine is really a cantilever biplane, and the interplane struts are intended mainly to stiffen the wings against torsional stresses.

A 55-hp. Siemens radial engine is mounted on four steel-tube struts from the top of the fuselage on a structure independent of the wing structure. The tank is built into the top plane forward of the engine. The total loaded weight of the plane is 660 kg. (1452 lb.), which includes a useful load of 462 lb. The original machine attained a top speed of 125 km. (78 miles) per hour at ground level, with a landing speed of 40 m.p.h. (*Flight*, vol. 18, no. 4, Jan. 28, 1926, pp. 43–44, illus., *d*)

Air Transportation

It is significant that this paper was presented not before an aeronautical society but before a railroad club. However, the Canadian Pacific was the first to actually print in its time table a connection with an air service.

Because of lack of space only certain parts of this interesting paper can be abstracted. As regards reliability, the author states that all aircraft can fly in bad weather and bad visibility, but it is the pilot who refuses to fly in weather conditions in which he cannot see. In flying through fog or clouds, the pilot fears that existing aircraft, when heavily loaded, may be thrown out of control, or lest his power plant should fail and force him to land through the zone of bad visibility, and he also still lacks full confidence in the wireless or compass as a means of knowing exactly where he is. If he flies below very low clouds, he is afraid of colliding with church steeples, tree tops, etc., or when he reaches his destination, he might find landing impossible on account of fog or very low clouds. Out of 4328 stage flights commenced, 4064 or 94 per cent were completed, without interruption and out of 264 stage flights interrupted, 105 were completed on the same day after the interruption. A total of 286 forced or involuntary landings occurred, excluding landings for refueling. The cause of the landings were weather 66 per cent, engine failure 34 per cent. Up to March 31, 1925, one aircraft of the Handley Page type and two of the de Havilland 34 type had each completed about 2300 hr. of flying, representing approximately 200,000 miles each, and 3 Napier Lion engines had each run on an average 1350 flying hours.

The various causes of engine failure were found to be 28 per cent water circulation system, 10 per cent valve breakage or distortion, 10 per cent oil circulation, and 43 per cent breakage of material, such as cracked crankcases and broken housings and casings. Of all these failures, only 7 per cent were so serious as to cause the immediate removal of the engine. The introduction of oil-burning engines, air-cooled, would do away with most of the present trouble.

No two-engine machine that the author knows of will reach its destination carrying a load with one engine out of action. In other words, twin-engine machines do not surpass single-engine planes for reliability. Three-engine machines are today in operation that are able to maintain horizontal flight with any one of the three engines out of action. Multiple engines are complicated and costly. Personally he believes the success of air transportation relies on getting an absolute reliable single motor.

Last summer the author personally made a trip from Prince Rupert into the unexplored regions of northern British Columbia and the Yukon, using a single-engine flying boat. The motor was a Napier Lion and the party was out of touch with civilization for about five months, and flew over a distance of 12,000 miles without any trouble whatever.

As regards costs of operation of air transport, the author points

out that at present about 30 per cent of the operating costs go to fuel and oil. In his opinion the possibility of an appreciable reduction in the cost of gasoline in the near future seems very remote, but economies may come from burning heavy oil. About 44 per cent of the total cost is consumed by maintenance and overhaul of engines. This may be eventually reduced by the adoption of all-metal aircraft. Insurance is also a very big factor in costs. Since 1919 insurance rates in Canada have varied between 12 and 30 per cent per year on the capital cost of aircraft, regardless of the number of hours spent in the air during the year.

The eventual success of air transport must depend on the traffic it attracts, and it is necessary to consider for a moment what the public wants. The standard of comfort in an aircraft in good weather is already high, and progress is being made toward the really satisfactory heating and ventilation of the cabins; but there are two factors of discomfort which demand the attention of designers, scientists and even doctors—noise and seasickness. The noise of the exhaust has already been reduced with some success, but the noise of the engine itself, and still more the noise of the propeller, are causes of considerable annoyance and discomfort to a certain number of passengers. The engine no doubt will grow more silent as designs develop; for instance, the sleeve-valve engine should be more silent than existing types, but the reduction of the noise of the propeller appears at present to be an insoluble problem. The best line of attack appears to be a thorough investigation of the problem of producing an approximately soundproof cabin.

The reason for air sickness has not yet been satisfactorily explained. It cannot be exactly the same as seasickness, for good sailors are often bad airmen and vice versa. The author suspects that noise and bad ventilation have had something to do with this trouble up to date, and in addition he rather suspects that the change of pressure caused by climbing affects some individuals adversely. In any case today air transport has undeservedly earned a bad reputation for causing sickness.

Real progress in the reliability of the engine and its installation, and an appreciable addition to its length of life before overhaul, will do more in the immediate future toward the attainment of perfect safety, great reliability, and high economy than any other development.

The total cost of operation today is estimated by the author at $1.25 a ton-mile. He gives statistics of operation and data as to commercial air transportation in various countries. (Lt-Col. Scott Williams, Mgr., Tractor Dept., Mussens Ltd., Montreal, in *Canadian Railway Club Proceedings*, vol. 25, no. 1, Jan., 1926, pp. 20–38, *g*)

AIR MACHINERY

A Rotary Compressor

DESCRIPTION of a compressor designed particularly for use in supercharging high-speed internal-combustion engines, but suitable for other purposes as well.

One of the troubles with rotary blowers or compressors is the tendency of the sliding blades to press against the cylinder, because of the action of centrifugal force. A solution of this question was proposed by Cozette in the blower shown in Fig. 1. Between the sliding blades of the rotor and the cylinder stator is introduced a hollow cylindrical drum rotating at the same speed as the rotor. With this arrangement the undesirable excessive friction due to centrifugal force is eliminated as the blades in running do not bear at all on the surface of the stator. As will be noticed from the drawing, the center of rotation of the intermediate drum is concentric with the stator, while the center of rotation of the rotor is eccentric to both of them. No information is given as to the method for driving the intermediary drum and for coördinating its speed with the speed of the rotor. (*Revue de l'Ingénieur*, vol. 23, no. 1, Jan., 1926, p. 14, *d*)

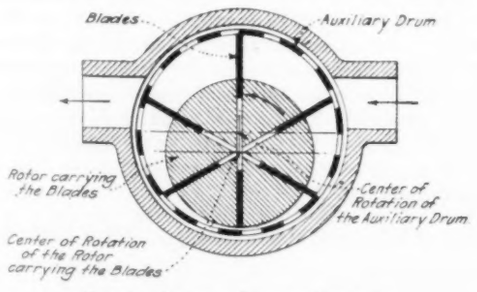

Blades
Auxiliary Drum
Rotor carrying the Blades
Center of Rotation of the Auxiliary Drum
Center of Rotation of the Rotor carrying the Blades

FIG. 1 COZETTE ROTARY BLOWER

ENGINEERING MATERIALS (See Machine Shop: Causes and Effects on Machinability of Hard Spots in Metals)

FUELS AND FIRING

Graphical Relation of Specific Gravity to Viscosity in the Case of Fuel Oils

THE author begins with a quotation from MECHANICAL ENGINEERING of July, 1925, p. 537: "Within the range 0 deg. fahr.–195 deg. fahr. the variation of specific gravity with temperature is to all intents and purposes, a straight-line function." He attempts to demonstrate that the above-quoted fact may be applied to deduce a graphical and mathematical relation between the viscosity and specific-gravity curves of a given oil whereby, its specfic gravity and viscosity and known temperatures being given, its viscosity at any other temperature may be predicted within sufficiently accurate limits for practical working purposes. He claims that it can be shown that specific-gravity curves like viscosity curves are straight-line functions, and when plotted to a double logarithmic scale the same as the viscosity curves, they meet at a point. He plots to a double logarithmic scale viscosity and gravity curves of fuel oils. Given one viscosity and one gravity determination and using the common mean point *A*, curves can be plotted and their relation analyzed by inspection. The mathematical relation of the curves is next considered. This part is not suitable for abstracting. A table is derived which, among other things, permits to determine the approximate viscosity and gravity of a fuel oil at any temperature below the limit of 220 deg. fahr., if its viscosity and / or gravity at another temperature are given. Numerical examples are given in the original article. (G. B. Vroom, Lt-Comm., U.S.N., in *Journal of the American Society of Naval Engineers*, vol. 38, no. 1, pp. 119–129, 1 table, 4 charts, *ptA*)

INTERNAL-COMBUSTION ENGINEERING (See also Motor-Car Engineering: A C Six-Cylinder Racing Engine)

A German Design of the Michell Crankless Engine

FROM the article it would appear that Michell designed his engine while in the employment of the Krupp Germania Yard. The original engine had two cylinders, but last year a three-cylinder unit was built, 6.3 in. in diameter with a stroke of 65 in. This engine, which runs normally at 110 r.p.m., develops 100 b.hp. and weighs about $6\frac{1}{2}$ tons. (*The Times Trade and Engineering Supplement*, vol. 17, no. 396, Feb. 6, 1926, p. 514, 1 fig., *d*)

The Attendu Heavy-Oil Engine

THIS engine has been under development since 1921. In 1924 a contract was secured from the Navy Department for the building of a two-cylinder experimental unit to determine whether a light-weight heavy-oil engine suitable for airship work would stand high compression pressure at high speed. This engine was designed to develop 100 hp. at 1500 r.p.m. or 125 hp. at 1750 r.p.m., and to have a weight of 3.8 lb. per b.hp.

The aviation engine was delivered to the engine-testing laboratory at the League Island Navy Yard in February, 1925, and after several tests and improvements on adjustments, especially on the lubricating-oil system, showed a brake-horsepower output of 85 at 1620 r.p.m. In the builder's own laboratory, however, an output of 91 b.hp. at 1525 r.p.m. has been obtained, and it is foreseen that, by making some alterations that are now in progress, an additional output of from 20 to 25 b.hp. can be obtained, thereby

bringing the engine up to 110 or 116 b.hp. for a total weight of 417 lb., or 3.6 lb. per b.hp. The fuel consumption is now in the neighborhood of 0.6 lb. per b.hp-hr., and it is expected that this can be reduced to 0.5 lb. per b.hp-hr. The maximum recorded speed is 2210 r.p.m.

The engine operates on the conventional cycle, but is designed so as to obtain a high degree of strength and rigidity and at the same time keep within low limitations of weight. Interesting details of the engine design and a description of the essential parts are given in the original article. (Andre C. Attendu, Consulting Engr., Montreal, Canada, in *the Journal of the Society of Automotive Engineers*, vol. 18, no. 2, February, 1926, pp. 214–221, 7 figs., *d*)

A New Fairbanks-Morse Marine Engine

THE principal improvements in this engine as compared with those previously built by the same concern are those which adapt the engine to the use of a wider range of low-grade fuels, better fuel economy, and means for immediate starting without the aid of auxiliary ignition devices. The engine is of the airless-injection type.

A few degrees before the compression has been completed, i.e., near the top dead center of the piston travel, a spray of fuel is introduced into the combustion chamber through a nozzle centrally located at the top. Partial combustion, which results in burning the fuel charge in the precombustion chamber to carbon monoxide (CO) with the liberation of a relatively small amount of heat, takes place as the first stage of the process, and the liquid fuel that has entered the cylinder combustion space is gasified. Because of the partial nature of the first stage of combustion there is no pressure rise of any consequence.

As the piston starts on the downward stroke, with the attendant rush of gases through the neck into the cylinder space, a considerable degree of turbulence and a thorough mixing of the air excess with the CO gas and oil vapor are brought about and the final combustion of the charge to carbon dioxide (CO_2) is completed.

Over 50 per cent of the heat due to the entire combustion is liberated in the second stage, but owing to the fact that the piston is then beginning to pick up considerable speed the expansion quite accurately neutralizes any rise in pressure which would otherwise result from the more extensive and complete second-stage combustion. So thoroughly has the system been worked out that flat-top indicator cards are obtained, and the engine works with spontaneous ignition of fuel and complete burning unaccompanied by pressure rise, according to the method first conceived by Diesel.

Because of the use of a low velocity of fuel-oil jet, it is possible to employ definitely large atomizers and injection-nozzle diameters. Actually the nozzle diameter is $^5/_{64}$ in., and the helical stem placed just ahead of the nozzle, has grooves of nearly the same size. It is claimed that the general control scheme is very simple. Since the amount of fuel injection is dependent on the load carried by the engine, the suction valves have to be placed under governor control. An interesting feature is the design of the upper end of the piston used in this particular machine.

An important advantage of the two-stage combustion scheme is that its success is not dependent on the use of the fine multiple orifices in the fuel-injection nozzles or the use of high injection pressures. An interesting feature is the approximate equalization between the velocities of the oil jet and the air entering through the neck toward the end of compression. It was established that an insufficient velocity did not give the best results because of deficient turbulence, and that an excess of velocity had a tendency to throw the fuel back against the cooler portions of the combustion chamber. Careful design and precision in manufacturing methods have made it possible to secure the proper balance between air and jet velocities.

An interesting feature of this design is the use of what the engine builders term "two-stage combustion." A crown of substantial thickness is used, not so much for the sake of strength as for providing an adequate section for the transmission of heat. Also, there is a gradual taper in the thickness of the piston section from the under side of the crown to the interior of the barrel, and the extra metal at this point further carries out the idea of providing for a free flow of the heat.

It has been found that the side surfaces of piston rings are one of the most effective means for getting the heat of the piston away to the walls of the cylinder and thence to the jacket, a consideration which has been borne in mind in providing this engine with six piston rings. They not only serve as a means for sealing the compression, but also have an important bearing on the matter of keeping the piston crown cool.

The original article describes many other features of design, particularly the lubrication. (*Motorship*, vol. 11, no. 2, Feb., 1926, pp. 113–118, illus., *d*)

MACHINE PARTS AND DESIGN

A Magnetic Ammonia-Compressor Valve

IN A PAPER presented to the Victorian Institute of Refrigeration at Melbourne, Australia, H. J. Hilton pointed out that no time during the suction stroke does the charge of gas in the cylinder equal in density that of the source from which it is drawn, the spring-weighted suction valve of the compressor acting as a reducing valve. The spring force on the valve being constant, the efficiency of the machine is adversely affected as the back pressure becomes less. To overcome this condition Mr. Hilton has devised a valve which opens to its fullest extent at the beginning of the suction stroke and remains so throughout the entire stroke. Inside the cap of the valve is a solenoid with a soft-iron core. Electric connections are made to a commutator on the crankshaft, the contact being made and broken at the proper centers. Application of current opens the valve instantly, and at the break of the circuit the spring immediately closes the port. (*Refrigerating Engineering*, vol. 12, no. 7, Jan., 1926, p. 214, *d*)

Helical Springs

AN INVESTIGATION into the relation of actual to calculated performance. Tests were made to determine the following points: the modulus of elasticity; the elastic limit; the effect of the end turns in compression springs, and the breaking stress in tension springs.

While of interest, the article is not suitable for abstracting and only some of the conclusions can be reproduced here. It was found that the principal causes of divergence between the actual and calculated performance of springs are as follows:

Use of Incomplete Formulas. The error for springs of ordinary dimensions is negligible and the formulas, though incomplete, are sufficiently accurate for all practical purposes. In fact, there would be no advantage in using the more complicated complete formulas for the calculation of either compression or torsion springs.

Alteration in Shape of Section of Wire Due to Coiling. Here again the difference in the majority of cases is not very essential.

Dimensional Errors in Manufacture. These may be considerable in some cases, and the author cites an instance where the inaccuracies in the dimensions cause an increase of 13 per cent in the stress and 30 per cent in the deflection.

Error in Estimation of Modulus of Elasticity. A table is given in the original article showing large differences in the value of modulus of elasticity. Until greater uniformity can be obtained in this value it is impossible to be certain that the performace of a spring will be in accordance with the designer's intention. The author suggests that some standard should be established for the modulus of elasticity. (Claude W. Hill in *Machinery* (London), vol. 27, no. 697, Feb. 4, 1926, pp. 601–607, 7 figs., *t*)

MACHINE SHOP

Causes and Effects on Machinability of Hard Spots in Metals

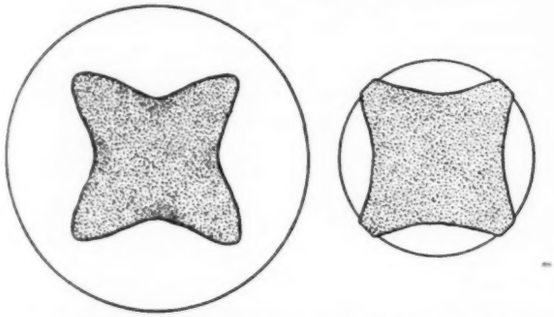
THE most interesting part of the article is that dealing with steels, in particular, carbon steels. The main cause of hard spots in this case is segregation, which can be traced back in practically all cases to the ingot. It is the cause of uneven free-machining properties in many steels.

It is a simple matter to prove the presence of segregation in steel by taking sulphur prints. The process consists of first cutting a section of the steel and roughly polishing the freshly cut surface. A piece of ordinary photographic bromide paper is taken and is immersed in a 5 per cent solution of sulphuric acid in water for a

few minutes. The majority of the dilute acid is then allowed to drain off the paper, which is placed on to a section of steel, is allowed to remain there for about one minute, and then removed. This completes the operation, and the acid may be washed off and the print dried. The presence of manganese sulphide is shown as black spots. If these spots are uniformly distributed throughout the metal as small dots, the material is good. If they occur bunched up in a few places or in the form of large lumps, the material is segregated. Although a sulphur print indicates only the position of the manganese sulphide, it is known that if this component is segregated, so are usually the other elements of the steel. Among these is carbon, and if this is present in greater proportion in one part of the steel than in other parts, the machining properties of the steel will vary very considerably.

FIG. 2 SULPHUR PRINT OF BADLY SEGREGATED STEEL

If the only trouble with segregated steel were that the inside portion was harder than the outside, it would be a simple matter to machine the outside portions at a constant speed, and leave the inside portions to look after themselves. Unfortunately, however, this cannot be done with the majority of forgings, for the reason that rolled bars of square or gothic section when forged and swaged round the segregated portion of the steel are affected in a somewhat



FIGS. 3 AND 4 ILLUSTRATING THE SHAPE TAKEN UP BY THE SEGREGATED PORTION OF STEEL SHOWN IN FIG. 2 AFTER FORGING ROUND. FIG. 4 SHOWS THE EXAGGERATED EFFECT OF MACHINING A BAR SIMILAR TO THAT SHOWN IN FIG. 3

peculiar manner. This is illustrated in Fig. 3, which shows the position of the segregated portion of steel bar shown in Fig. 2 after forging round in swages. If such a round bar be turned in a lathe it is evident that the tool will first encounter soft material and then hard segregated material, and although the cutting tool will cut both portions it will not cut them with equal facility, as the tool will tend to jump over the harder portions. This will produce an effect similar to that shown in an exaggerated manner in Fig. 4.

This matter of segregation in steel can explain a whole host of troubles which are commonly experienced in the maching of this alloy. For example, there are many engineering components which require the drilling of long, narrow holes which must be dead straight. It is sometimes found that it is impossible to drill these holes quite straight for the reason that the drill tends to go off at a tangent. In many cases the machinist is blamed, while on other occasions the cutting compound is thought to be at fault. As a rule, however, segregation is at the root of the trouble, because it is natural that if the drill encounters soft steel at first, and then runs against harder segregated steel on one side, it will not cut the harder portion so easily, and will run out straight. In passing, it may be mentioned that patches of segregation, due to forging segregated steel, are often responsible for the mysterious lifting of the surface of steel which has been maintained. This is more especially noticed after such articles have been case-hardened and hardened, and unless segregation is thought of, it is impossible to evolve a satisfactory explanation of the trouble.

From the above it will be realized that it is folly to purchase steel which is badly segregated unless the bad portion is gotten rid of by punching out. A great deal, possibly the majority, of steel is bought without taking sulphur prints to prove its soundness. This is not good policy except for the commonest steels, or those which are bought as free-machining steels, which are usually to be merely skimmed upon their surfaces. A sulphur print is very easily and cheaply taken, and there is no doubt that the taking of such a print and an analysis will furnish a buyer with much more valuable information than will the customary tensile test, the results of which can easily be so misleading. ("Met." in *Machinery* (London), vol. 27, no. 696, Jan. 28, 1926, pp. 569–572, 5 figs., *p*)

MACHINE TOOLS

A New Swiss Automatic Screw Machine

DESCRIPTION of a machine of Swiss manufacture handled by an English concern and built in a range of three sizes suitable for $^{13}/_{64}$-, $^{1}/_{2}$-, and $^{5}/_{8}$-in.-diameter bars, respectively. An automatic screw-head slitting device is embodied in the mechanism; formed and knurled parts can be made quite readily. The whole of the mechanical movements are controlled by two camshafts dispossed at right angles to the spindle, one at each end of the bed; the cams mounted thereon in conjunction with adjustable inclined planes enabling most work for which the machine is suitable to be produced by one standard set of cams.

Fig. 5 shows the leading mechanical features in plan. The work spindle *A* is a hardened steel member, accurately ground and running in phosphor-bronze bearings in a headstock *B*, which slides on a horizontal guide on the top face of the bed. A patented two-jaw chuck is incorporated in the spindle nose for gripping the bar, and is adjustable so that there is no need for collets to accommodate different sizes of bar. Drive to the spindle is through a belt pulley *C* and clutch *D*, and an automatic brake *E* permits of the spindle being stopped suddenly when threading operations are in progress.

Turning, forming, and parting tools are mounted in front, back, and overhead slides *F*, *G*, *H*. The spindle *K* directly opposes the work spindle, and is designed to carry a die holder. It is driven by fast and loose belt pulleys, and consists of a main outer spindle with an inner secondary spindle at the front end, which is pushed forward to apply the die to the work. To release the die from the work after threading, the belt fork and automatic brake are manipulated; i.e., when threading, the work spindle is stopped by the brake, and to release the die the work spindle is started, thus overrunning the slower moving die-head spindle.

Before parting the screws from the bar a socket holder *M* swings over into line with the work spindle, and moves forward over the screw, which is then parted off. The holder immediately swings back to its present position and moves forward so as to bring the screw head into contact with a small saw at *N*, which slits the head for the screwdriver. The holder then moves backward—that is, toward the left—and the screw is ejected by an adjustable stop rod in the member *L*. It may be noted that the slitting operation takes place while the next screw is being turned, so that the rate of production is not interrupted.

The cams operating the various slide movements are mounted on the transverse shafts *OP*. Those to the right control the bar feed, spindle chuck, clutch and brake, and traverse of the headstock, which is utilized for sliding operations instead of traversing the tool slides. The cams on the left-hand shaft control the die-head spindle and the screw-slitting arrangements. All the cams are of simple design, and when necessary they can be easily adjusted or removed. The camshafts are rotated in unison by means of worm gearing driven from a horizontal backshaft carrying a 5-step cone pulley. This permits of suitable variation in the speed at which the cycle of automatic movements is performed.

In most cases the cams operate direct through the medium of pivoting levers, and, to provide a ready means of adjustment

for the tool slides, these are provided with apparatus of which that applied to the front slide may be described. As seen at *R*, there is an extension attached to the front of the slide *F*. This bar has a cam bowl on the under side which is in contact with an inclined plane *S* that swings on the fillister-head screw *T*. To operate the slide *F* the slide carrying the inclined plane is spring loaded, and is pushed forward by one or other of the two plungers *UV*. By these means a very wide range of adjustment is provided, or, in other words, a wide variation in slide travel is obtained from the same cam, as by simply increasing or decreasing the angle of the inclined plane the slide can be made to travel a longer or shorter distance as required. It may be further noted that the tool slides have independent longitudinal adjustment, and are fitted with simple holders for carrying the cutting tools. (*Machinery* (London), vol. 27, no. 698, Feb. 11, 1926, pp. 652–653, 2 figs., *d*)

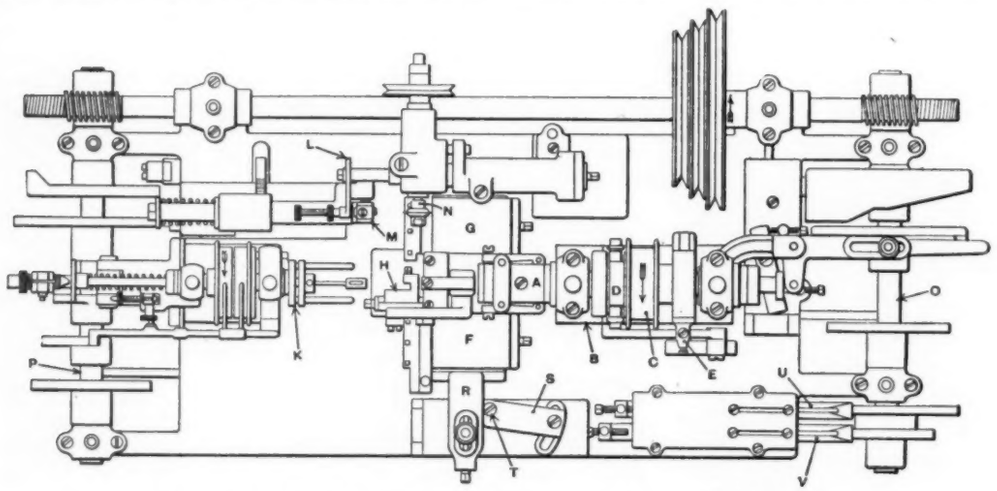


Fig. 5 Plan View Showing Screw Machine in General Arrangement

MEASURING APPARATUS

A Telerecorder for Distant Flow Measurements

Description of the Kent telerecorder. The steam meter made by the same firm, George Kent, Ltd., of Luton, England, was described in Mechanical Engineering, vol. 47, Sept., 1925, p. 752. The present article deals with a boiler-load indicator made to show the rate of steam flow or evaporation. The mechanical movement of the indicator is arranged to actuate a cylindrical winding which is movable within a stationary primary, on the lines of an induction regulator. By this means a definite voltage is induced in the movable winding according to its relative position, and this is utilized in the pressure coils of the graphical and integrating recorders, producing one component toward the provision of a diagram chart and a counting mechanism. The other component essential to the operation of such instruments is akin to a "current" winding put in series with the transmitter primary coil. By calibrating the "wattmeter" in suitable units it may be made to integrate the instantaneous rate of flow with time, giving a total quantity during a period just as in the case of an electricity meter. The graphical recorder will also draw a load curve showing how the flow varies.

From this it appears that it is the movement of the movable winding that gives the indication by its relative position. To understand how this movement is produced it is necessary to remember that the load indicator itself is primarily a diaphragm supported on either side by heavy springs, under the influence of the difference of pressure due to an inserted orifice in the pipe line. The present article deals mainly with the methods by which the indications are transmitted from the diaphragm to the testing and recording instruments. (The *Power Engineer*, vol. 21, no. 239, Feb., 1926, pp. 65–66, 4 figs., *d*)

METALLURGY (See Machine Shop: Causes and Effects on Machinability of Hard Spots in Metals)

MOTOR-CAR ENGINEERING

A C Six-Cylinder Racing Engine

Description of a new type of engine British manufacture, in which the water jackets, crankcase, sump, head, and camshaft covers are of aluminum alloy, while the cylinders are cast-iron liners.

An interesting feature of the engine is the valve gear. Into each head are screwed seatings for the two valves. Floating guides allow the valves to center themselves, volute springs being used in order to economize space; each coil is of considerable depth so that there is no danger of overlapping and jamming the valve. Instead of the usual cotter attachment the upper end of the valve stem is provided with four vertical slots much like keyways, but staggered. Into the slots fit snugs on the back of the three sections of steel, which together form a cone cotter and are held in position once the valve spring is released and its retaining washer grips the cone.

There are two camshafts driven by a single chain from a gear wheel, which in its turn is driven from the crankshaft through reduction gearing to reduce the speed of the chain to prevent slackness altering the valve timing; a broad leaf spring presses on the back of the chain while it is running, maintaining constant tension.

The engine is of the supercharged type. The supercharger is coupled directly to the front of the crankshaft and has a blower with three aluminum blades. It is provided with a safety valve in case an explosion should occur in the inlet pipe, and a smaller bypass valve which can be set to limit the pressure in the inlet pipe. The supercharger sucks the explosive mixture from the carburetor and forces it to the cylinder. (The *Autocar*, vol. 56, no. 1581, Feb. 5, 1926, pp. 217–218, illus., *d*)

PHYSICS

Films

In a lecture at the Royal Institution in February, 1926, Sir W. B. Hardy proposed to add to the three states of matter—solid, liquid and gaseous—as a fourth state such thin films as are met with in soap bubbles and in journal bearings. Every physical constant whether referring to viscosity or anything else, is quite different in a film from what it is in any one of the other three states. Moreover such films not merely constitute a fourth state of matter, but this fourth state is of the greatest importance, since living matter depends upon these films for its continued existence.

The speaker discussed particularly the effect of oil films on water —what is known as the stilling effect on waves—first pointed out in 1773 by Benjamin Franklin. (*Engineering*, vol. 121, no. 3136, Feb. 5, 1926, pp. 175–176, *g*)

POWER-PLANT ENGINEERING (See also Testing and Measurements: The Credibility of Boiler Tests)

Italian Steam Apparatus for Utilizing the Internal Heat of the Earth

When first established the "soffioni" plants of the Borax Company at Larderello and Terra del Lago used Kestner evaporators. These have since been completely replaced by the Bringhenti device shown in Fig. 6. The purpose of this device is to produce steam substantially free from non-condensable gases, which latter constitute 6 per cent by weight in the discharge of matter at Larderello and 4 per cent at Lago.

The principle of this apparatus involves a circulation between two receptacles closed to the outside but communicating with each

other, of a predetermined quality of water, which absorbs the heat in one receptacle only to restore it in the next. Use is made of the property of the gases not to condense at the prevailing conditions of the pressure and temperature, which prevents them from uselessly losing their elastic force.

In the Bringhenti device the steam from the soffioni enters through the perforated tube *S* and bubbles through the water contained in boiler *C*. The steam condenses while the non-condensable gases accumulate in the upper part of the boiler, whence they are permitted to escape through valve *B;* these gases still contain some water vapor, but only in a very small quantity as the partial pressure of the steam in the mixture cannot be but very low because of the large quantity of other gases present. The water of boiler *C*, freed from the pressure of these gases (this pressure being regulated by valve *B*) passes through tube *A* into the vertical cylinder *V*, where it expands and vaporizes in part, giving a steam essentially free from gas. The remainder of the water, cooled due to heat expended to form steam, is forced back to boiler *C* by pump *P*, which completes the cycle of transformation.

The efficiency of the apparatus is higher than that of a tubular

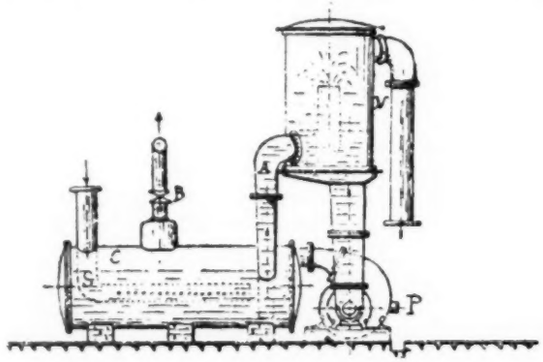


FIG. 6 THE BRINGHENTI DEVICE USED TO PRODUCE STEAM FROM UNDERGROUND HEAT AT LARDERELLO

vaporizer and goes as high as 95 per cent when referred to the effective quantity of the steam contained in the original mixture. The vaporization taking place in the receiver *V* may with good approximation be considered as taking place adiabatically, which makes it possible to determine all the quantities that enter into the cycle from the entropy diagram.

At the Larderello plant there are produced from three such apparatus approximately 23,000 kg. (50,600 lb.) of pure steam per hour. The horizontal boiler has a diameter of 2.2 m. (86.6 in.) and a length of 6.5 m. (21 ft. 3 in.). It receives a pressure of about 2 atmos. abs. The water passes from the horizontal to the vertical receiver through a pipe 500 mm. (19.6 in.) in diameter and the vertical receiver is a cylinder 2.5 m. (98.4 in.) in diameter and 4 m. in height (13 ft. 1 in.). After giving up its heat the water passes into a pipe, 600 mm. (23.6 in.) in diameter, which leads to a 35-kw. electrically driven pump, which latter delivers the water again to the horizontal boiler. The steam produced in the vertical receiver has a pressure of about 1.65 atmos. abs., and each kilogram of steam contains about 36 liters (1.27 cu. ft.) of various gases. A fourth unit has been at work in Lago for about two years and has been producing 5500 kg. (12,100 lb.) of steam per hour.

There has never been any occasion to carry out any repairs on these apparatus and the efficiency has been absolutely constant, which is explained by the fact that there is nothing to produce a variable thermal efficiency in them and that the apparatus do not suffer from scaling, corrosion of tubes, etc. (*L'Industria*, vol. 39, no. 18, Sept. 30, 1925, p. 481, *d*)

RAILROAD ENGINEERING

Tests of Three-Cylinder Locomotive on the U.P.

TESTS were recently carried out by the Union Pacific Railroad in which the operation of a three-cylinder 4-10-2 type engine was compared with that of a two-cylinder locomotive of the standard type used by that railroad in heavy freight service. Data of the two machines are given in the original article.

From these tests it would appear that the three-cylinder engine hauled 544 more tons over the district in 3.4 hr. less time than was required by engine No. 5007. Furthermore, in making this performance, engine No. 8000 used 222 lb. less coal and 1870 lb. less water. This, of course, made a difference in the amount of fuel consumed for each 1000 gross ton-miles, which in this case was 20.8 lb. less.

About the same results were obtained in the other tests, and as an average the maximum tonnage hauled by engine No. 8000 was 18.8 per cent more than that of engine No. 5007. The average amount of fuel consumed by the three-cylinder engine for 1000 gross ton-miles was 90.9 lb., where that for the two-cylinder engine was 105.6 lb., a difference of 16 per cent.

The examination of the locomotive at the time of the tests disclosed that the driving-box bearings were in good condition and that all brasses were tight in the boxes. All main- and side-rod bearings were found in good shape, and no new brasses had been applied. (W. W. Baxter, Editor, Mechanical Dept., *Railway Review*, in *Railway Review*, vol. 78, no. 6, Feb. 6, 1926, pp. 251–256, illus., *e*)

Locomotive Boiler Pitting

THE original title of the article here abstracted is Pitting—A Myth or a Menace? The conclusion to which the author comes is that it is a very real menace and only partly conquered. He sees the brightest promise for the future in the fact that serious attention is being paid to the subject not only by the engineers but even by the highest management of the railroads.

Only a few years ago the general feeling among investigators was that, in the words of S. W. Parr of the University of Illinois in 1906, "the problems connected with railway (water) service involve no very profound chemical principles." This view has been entirely abandoned and the problem is considered to be now a very complicated one, involving, in particular, electrolytic action. Without going into the many details presented by the author, it would appear that consistent with this conception the causes of corrosion are limited only by the conditions that will produce electrolytic action in the boiler, while the preventives are limited only to those conditions, agencies, substances, etc. that will restrict electrolytic action. Thus while pitting (comprising all localized corrosion except grooving, which is the cutting of flues adjacent to the flue sheet) contemplates a region of sharp differences of potential, it is conceivable and it has been demonstrated that this difference of potential may not result necessarily from the imperfections here and there in the chemical composition of the flues and sheets, but equally from the presence of points of unequal stress or from contact with other substances. It is likewise conceivable under this theory how a coating of scale or other material may protect in some cases and not in others; how corrosion may proceed in alkaline water; or even how temperature differences in the boiler may possibly be instrumental in the destructive process—the latter a thought of particular merit pending investigation for the aid it gives in explaining the grooving action. But especially the electrolytic aspect of boiler corrosion affords a more comprehensive basis upon which to examine waters and undertake their correction, and also for finding the immediate causes of pitting outbreaks. The recognition which members of the Water Service Committee of the American Railway Engineering Association and others on railroads are now according this understanding of boiler corrosion after several years of discussion, and the interest manifested in learning more about it, are considered quite as decisive a step toward the solution of the pitting problem as is the attitude of boiler-trouble students expressed in the representative statement that "the more study this question has been given the less it was realized was known about the subject."

But again, progress in pitting control has not been confined alone to acquiring the modern conception of the process. Instead a marked advance appears to have been made in the study and application of cures. Of the events in this field probably the one of most practical importance is the general acceptance of discoveries to the effect that sufficiently concentrated solutions of caustic soda (NaOH) and carbonate of soda (Na_2SO_4) are inhibitors of corrosion. The problem contingent upon the use of these chemicals to the degree said to be necessary to the purpose, is that of avoiding

foaming (for both are foaming salts), but the tone of reports of various experiments already carried out in railway service where the foaming trouble has apparently been met, tend so to confirm the earlier investigations of Cushman, Walker, and others, and particularly the experiments conducted by the U. S. Navy in 1912, that increased efforts to apply this remedy for pitting in some form or other are certain. The fact is that some of these reports indicate that well-directed efforts in this direction have been successful.

While the above events are of the greatest importance in every consideration of pitting at the present time, it is also significant that other studies are now progressing on railroads which invite attention. Most prominent among these, perhaps, is the study being made of the effect on pitting of dissolved oxygen, a substance that was mentioned among corrosives considered by some as early as 1904, but which was not given serious thought until after the work of Cushman and others, mentioned above. On the theory that this oxygen is the controlling factor in pitting in some waters by oxidizing and thereby continuously removing the ionic iron as it is produced under the electrolytic action, and on the strength of certain laboratory experiences and observations of pitted flues which are said by its advocates to strengthen the theory (notwithstanding current doubts of its effect in boiling water), various tests are now being made with feedwater heaters in an effort to remove it before the water reaches the boiler. Thus the feedwater heater becomes a more important facility, for the present at least, than merely that of a fuel economizer. The Pennsylvania and the Chicago, Milwaukee & St. Paul are among the roads conducting such experiments.

Other experiments being conducted at the present with the hope of correcting pitting, from which its advocates expect much, involve the counter-electrical method of treatment, a treatment which is patterned after a practice claimed to have been applied successfully in certain marine boilers.

Also there is a recognition of the paramount importance of the quality of boiler metal. W. A. Powers, former chief chemist of the Santa Fe, says that he has investigated a large number of pitting epidemics both on boiler tubes and firebox sheets, and has never found a case in which the pitting was not due either to poor material or uneven strains caused by improper staying. Particular importance is attached to this latter factor. (D. A. Steel in *Railway Age*, vol. 80, no. 8, Feb. 20, 1926, pp. 467–474, illus., *hptA*)

The McClellon Water-Tube Locomotive Boiler

DESCRIPTION of a boiler developed on the New York, New Haven & Hartford Railroad. One of these boilers was experimentally used on the New Haven Railroad for a number of years. A modified design was then built and tested so successfully that ten new engines recently purchased for the road were equipped with this type. The boiler was originally designed by James M. McClellon, of Everett, Mass., who died just as the boiler had demonstrated its efficiency, and is now the property of the McClellon Locomotive Boiler Co., of Boston, Mass. The present design was worked out by W. L. Bean, Superintendent of Motive Power of the New Haven road.

The details of construction are seen from Figs. 7 and 8. The sides and back end of the firebox are formed of water tubes, as are also the sides of the combustion chamber. What corresponds to the roof and crown sheets is formed of three drums extending longitudinally over the whole length of the firebox and the combustion chamber, and attached at the front end to the back tube sheet. These drums are set in contact with each other and flattened; they are then riveted together. The flattened sides at the points of contact converge downwardly so that the central drum fits between those at the sides like a keystone, thus providing a very strong assembly. With this arrangement the level of water in the crown may be lowered to a considerable degree without exposing any surface uncooled by water to the heat of the fire. In order to relieve the side-wall tubes of any structural loads other than those occasioned by reason of their containing hot water under pressure, the drums are supported from the mud ring by a system of struts at the firebox portion. The drums and mud ring are fastened together by braces which are channels bolted to the drums and mud ring and tied together by a horizontal piece. This arrangement of the bracing which is free from triangulation permits of a comparatively free longitudinal movement of the drums relative to the mud ring, without putting an undue stress on any part. At the same time the firebox tubes are relieved of all structural loads. Shocks incident to service are transmitted through this bracing construction and kept away from the tubes to a noticeable degree as evidenced by the water tube staying tight even under severe and unusual operating conditions.

There is an extension of the boiler shell back of the back tube sheet overlapping the forward portions of the crown drums. This extension houses the water tubes in the combustion chamber and supports the circulating trough. This latter is a sheet bent to a U-section and riveted to the bottom of the shell. Along the line of attachment of the trough to the extension of the shell the latter is cut with a series of holes through which the combustion chamber tubes communicate with the circulating trough. This dry shell is an important part of the construction in that it gives the necessary strength for connecting the firebox portion of the boiler to the barrel section. It serves as an envelope for the combustion chamber and prevents any hinge action between the barrel and the firebox.

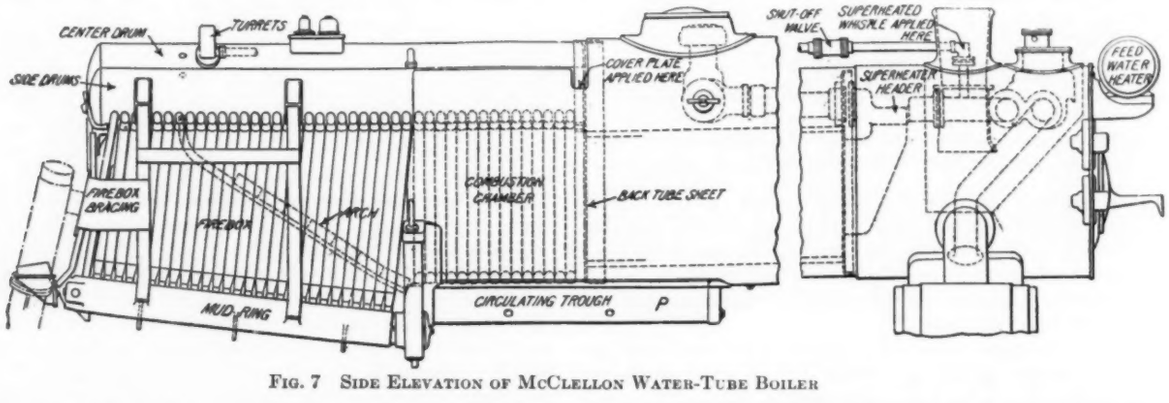


FIG. 7 SIDE ELEVATION OF MCCLELLON WATER-TUBE BOILER

While no investigation has, thus far, been made as to the character and direction of the circulation in this boiler, it seems probable that the water after entering the shell at the injector check drops to the bottom and moves back until it reaches the large hole that opens into the circulating trough; then it drops back and moves with considerable rapidity, losing speed as it moves back through the trough and the mud ring, because of the continual decrease in the quantity of water passed because of the upward currents taken from it by the tubes of the combustion chamber and firebox. That this circulation is quite rapid is evidenced by the fact that all of these parts are found, after a long service, to be quite free from mud and scale.

That this method of circulation in the boiler is the one that obtains is confirmed by observations on the bare boiler when fired during construction without any lagging or insulation whatever, when a very uniform heating and warming of the entire boiler from front end to back head occurred without the usual unequal warming and heating normally experienced in the radial stayed construction. In addition, the time required to fire up the cold boiler is noticeably less, and is approximately only two-thirds of the time experienced with the radial stayed construction.

It is evident that the greater the rapidity of this circulation the greater will be the equalization between the temperatures of the drums and the mud ring, and consequently the less will be the bending stresses put upon the tubes of the firebox and combustion chamber. As no trouble is now experienced with any of these parts, it is evident that the stresses due to unequal temperatures are greatly reduced and that the strength of the boiler is quite sufficient to resist those that do exist.

Some of the other features of the boiler are that there are two independent turrets, one for saturated and one for superheated steam. The turret for saturated steam takes its supply from the

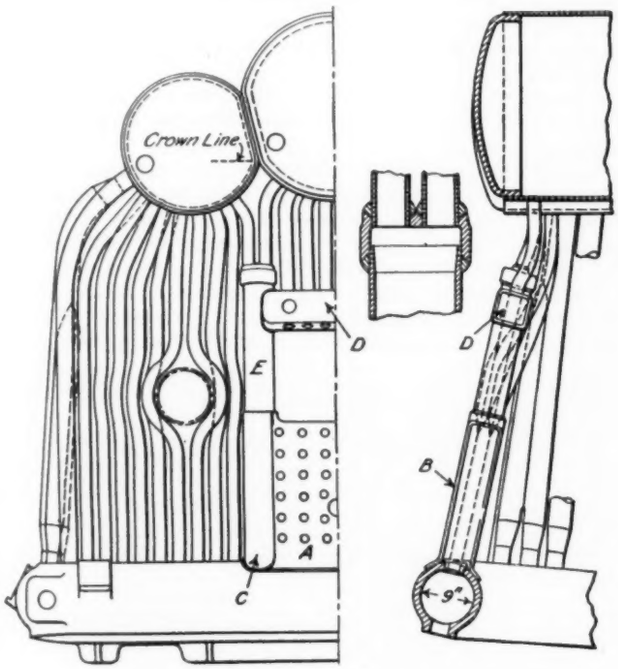


FIG. 8 BACK END OF MCCLELLON FIREBOX

center drum in the conventional manner. The superheated turret is supplied through a dry pipe connected to the main steam pipe on the left-hand side between the superheater header and the throttle in the smokebox as shown in the boiler (Fig. 7). A shut-off valve is provided near the front end. This superheater turret is mounted on the center drum and has no steam connection other than the one to the header. Superheated steam is supplied from the turret to the feedwater heater, the blower, the stoker, the dynamo, and the air pump, while saturated steam is supplied from that turret to the steam heating lines, the lubricator, the injector, and the drifting valve.

A locomotive equipped with the McClellon boiler was tested in comparison with a firetube radial-stayed type on two locomotives of essentially similar construction and dimensions. (The maximum cut-off for the McClellon was 70 per cent and for the other 85 per cent.) These tests have shown a decrease of 10.7 per cent in the total coal fired and almost the same decrease in the amount of coal fired per square foot of grate. Partly the boiler and partly the engine must be credited with the 15.1 per cent saving in the dry coal burned per 1000 gross ton-miles. But entirely to the boiler is credited the increase of 12 per cent in the actual evaporation per pound of dry coal and the increase of 11.5 per cent in equivalent evaporation, to which is added 2.5 per cent increase of actual evaporation per square foot per air of evaporating heating surface. The total increase of boiler efficiency in favor of the new boiler is 9.4 per cent.

The McClellon boiler pressure was 250 lb. as compared with 200 lb. on the standard locomotive. Due to the high boiler pressure and limited cut-off of engine No. 3500, a saving of 7.2 per cent in pounds of water per i.hp-hr. was obtained, which when added to the 12.0 per cent increase in pounds of water evaporated per pound of coal, resulting in a decrease of 19.6 per cent in dry coal per i.hp-hr.

This increased efficiency of 9.4 per cent over the standard boiler of engine No. 3324, when added to the decrease of 7.2 per cent in pounds of water, would indicate a total overall increase in thermal efficiency of 16.6 per cent. However, due to the increased boiler pressure of engine No. 3500, there is a resulting loss in machine efficiency of 1.1 per cent, leaving a total overall thermal efficiency of 15.5 per cent. (*Railway and Locomotive Engineering*, vol. 39, no. 2, Feb., 1926, pp. 31–39, illustrated, *d*)

REFRIGERATING ENGINEERING (See Machine Parts: A Magnetic Ammonia-Compressor Valve)

TESTING AND MEASUREMENTS

The Credibility of Boiler Tests

DURING the last year or so there have been published numerous boiler-test results in which efficiencies of over 90 per cent, based on the higher calorific value of the fuel, have been recorded. In one case an efficiency as high as 92.9 per cent has been claimed. There is no reason to doubt the good faith of those who put forward figures of this kind. They have presumably convinced themselves that their results are correct, and they generally support them by accounting with great exactness for the remaining 10 per cent or so of the heat which has not found its way into the steam. It is, nevertheless, questionable whether other engineers attach quite the same weight to them as their authors do. The figures are undoubtedly within the limits of physical possibility, and in many branches of engineering higher efficiencies are obtainable. Moreover, if the recorded weights and measurements of the tests are accurate, the efficiencies claimed follow as a matter of simple arithmetic. The credibility or otherwise of the results, therefore, turns entirely upon the reliability of the figures from which they are computed. This statement, although it looks like a mere truism, really contains the heart of the matter. What exactly, then, do we mean by reliability, and how can we measure it? Reliability is not to be confounded with precision. The more precisely an experimental result is expressed, the more cautiously should it be received. It is, indeed, the very preciseness with which the results of boiler tests are stated that gives rise to doubt. To say, for example, that a boiler showed an efficiency of 92.9 per cent means, if it means anything at all, that the speaker is sure that the true value is greater than 92.85 per cent and less than 92.95 per cent. Otherwise the final figure would be changed. It is therefore implicitly claimed that there is no possible error in the result greater than five parts in 9290, or, in other words, that the statement of efficiency is accurate within plus or minus about 0.05 per cent. Such a claim is extraordinary enough, but when we find boiler efficiencies given, as they frequently are, to two places of decimals instead of one, thereby suggesting ten times the accuracy of the case quoted, it will be obvious how far the craze for precision has outrun the practical possibilities of accuracy. It is by no means easy to determine even the diameter of any inch bolt with an error not exceeding 0.00005 in., and yet the same order of accuracy is claimed for every boiler efficiency given to two places of decimals, in spite of the numerous and comparatively rough measurements on which the claim depends.

In the test to which we have referred the calorific value of the coal is given as 12,545 B.t.u. per lb., with an implication of accuracy within plus or minus about one part in 25,000. Now, no experienced coal tester would rely upon agreement within one part in 200 between careful tests carried out on the same sample of coal by the same individual using the same apparatus. With independent samples, independently tested, there are likely to be variations of at least 2 per cent between one determination and another. During the twenty-two hours over which the boiler test extended there were burned over 130 tons of coal. The quantity actually burned in the calorimeter cannot have exceeded a few thimblefuls, and if we presume absolute accuracy on the part of the chemist and his apparatus, it takes a great deal of faith to believe that the microscopic fraction of the fuel which he examined was certainly typical of the bulk. How much confidence, therefore, can we repose in the statement that the average calorific value of the coal burned was 12,545 B.t.u. per lb.? If it were only 1 per cent higher, the boiler

efficiency would fall from 92.9 to less than 92 per cent at once. Then, again, there is the possibility of error in the weight of the coal burned. Weighing is supposed to be a very accurate process, and it certainly may be so. But, on the other hand, it may not; while even if it is, one has also to be sure that the time over which the weighed coal is burned is the same as that over which the evaporation of the water is measured. If the quantity of coal actually burned per hour is 1 per cent greater than that recorded, the boiler efficiency becomes still further reduced to 91.7 per cent. A further error of 1 per cent in the quantity of water evaporated per hour will bring the efficiency down to less than 90.2 per cent. Finally, if the recorded average pressure and temperature of the steam are both 1 per cent higher than their true values, and the recorded temperature of the feedwater is 1 per cent less than it should be, the boiler efficiency drops nearly to 89.7 per cent, or some 3.2 points less than that claimed. It may, of course, be reasonably contended that all the errors of measurement are not likely to be in the same direction, and that therefore they will largely cancel out. According to the laws of probability, the coincidence that six independent measurements will all tend to produce the same kind of error in the result will not occur on the average more than once in thirty-two boiler tests. But the three measurements in which errors have the greatest influence—namely, the calorific value and the weights of coal and water—will have their errors in the same direction in an average once in every four boiler trials, which is quite enough to give cause for anxiety. Moreover, there is always the human element to consider. It may be taken for granted that everybody engaged on a commercial boiler test would like the performance of the boiler to show up as well as possible. Doubtful readings, therefore, may be given the benefit of the doubt, and the records may have a slight bias for this reason alone. (*The Engineer*, vol. 141, no. 3658, Feb. 5, 1926, p. 156, *gA*)

VARIA

Chromium Plating of Printing Plates

Description of a process used by the U. S. Bureau of Engraving and Printing for the reproduction of engraved plates (the process was developed in coöperation with the Bureau of Standards).

In this process about 0.0002 in. of chromium is deposited upon the nickel surface of an otherwise unfinished electrolytic plate. The results with about 1000 such plates show that the impressions are even better than when made from the originals, and that the plates will yield several times as many impressions as nickel-faced or case-hardened steel plates. It is also possible to deposit chromium on steel plates which have not been case-hardened and to secure from them greater service than from case-hardened plates.

In this process chromium chromate, a compound of chromic acid and chromium in the next lower state of oxidation, is used. There are several ways of obtaining chromium chromate. In the actual process at the Bureau of Engraving and Printing chromium carbonate is added to the solution (chromic acid and chromium sulphate). This dissolves with effervescence and forms chromium chromate, the presence of which is indicated by a nearly opaque reddish brown color in place of the deep orange of chromic acid.

With a given solution and acidity the cathode efficiency and the character of the deposit depend upon the temperature and current density. By varying these the following three kinds of deposits can be obtained: (1) A dull, frosty or burned deposit which may range in color from nearly black to light gray; (2) a brilliant smooth deposit that has a high luster of the base metal, even after hours of deposition; (3) a smooth but scant deposit with a bluish milky appearance.

The original article gives the details of the process. From this it appears that it requires careful and skilful handling, and is suitable as yet for certain purposes only. (H. E. Haring, Asst. Chemist, U. S. Bureau of Standards, Washington, D. C., in *The Metal Industry* (New York), vol. 24, no. 2, Feb., 1926, pp. 68–69, *d*)

WELDING

Tests on Welded Pressure Vessels

Data of tests made under the auspices of a research committee on pressure vessels organized by several institutions in coöperation with the Bureau of Standards. One of the purposes of the investigation was to determine whether the acceptance test in the proposed A.S.M.E. Code for Unfired Pressure Vessels would reveal defects in the tanks which would make them unsafe.

The hammer test specified in the code calls for "an impact test which shall consist of striking the sheet on both sides of the welded seam a sharp vibratory blow with a 2- to 6-lb. hammer with a handle similar to a blacksmith's striking hammer, the blows to be struck 2 to 3 in. apart and within 2 to 3 in. of, and on each side of, the seam—the blows to be as rapid as a man can conveniently strike a sharp, swinging blow, and as hard as can be struck without indenting or distorting the metal of the sheet." It was desired by the Committee to use a hammer test which would give a definite value of impact of each blow, and a 6-in. hammer dropped through a distance of 4 ft. was used for the test.

None of the types of construction used in the tests in question appears to have been in strict accordance with the Code for Unfired Pressure Vessels.

The tanks tested may be said to represent standard production of a number of manufacturers. In order to manufacture code tanks, therefore, it will be necessary for each of the manufacturers to revise his methods, since the only construction allowed in the code for vessels of large size calls for use of either forge-welded longitudinal seams or seamless tubing, in connection with a dished head butt-welded to the shell, if concave to the pressure, or inserted into the shell and crimped if convex to the pressure. Any other form of construction for code vessels which is not distinctly prohibited by the code must be submitted to the Committee for an interpretation.

A number of other comments of the provisions of the code are given. The following are the conclusions given in the Report of the Bureau of Standards upon the results of tests referred to in the present paper:

A hammer test cannot be relied upon to show more than a very few exceptionally defective welds.

The hammer test, as applied, apparently did not weaken the tanks.

Hydrostatic pressure 1½ times the working pressure showed only a small number of imperfect welds, even when the hammer was used.

Hydrostatic pressure sufficient to stress the shell to the yield point will show a large proportion of imperfect welds.

Hydrostatic pressure sufficient to produce a permanent set in the shell, enlarging the circumference ½ per cent, apparently does not weaken the tank.

In the discussion which followed, other comments were made on the proposed code. L. H. Burkhart[1] confirmed the statement that a hammer test could not be relied upon to show up the leaks. He did not believe that it would affect the well-done fusion-welding joint, but objected to the test on the grounds that it was unnecessary and of no value. When a pressure vessel had been designed with a factor of safety of five and with an efficiency of joint of 80 to 90 per cent, then a test pressure of twice the working pressure should be applied to all fusion-welded vessels.

F. L. Fairbanks[2] claimed that the report in question was really the Report of the American Welding Society which had been published in quite elaborate form and in detail and had been before the Code Committee for approximately one year before the final proof of the code had been published. (Paper by L. H. Roller, Chief Engr., Ice Machine Dept., De La Vergne Machine Co., New York, N. Y., Mem. A.S.M.E., presented before The American Society of Refrigerating Engineers, December, 1925, and published in *Refrigerating Engineering*, vol. 12, no. 7, Jan., 1926, pp. 215 and 235–237, profusely illustrated, discussion pp. 237–241, *eA*)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general; *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

[1] Chief Engineer, Struthers-Wells Co. Mem. A.S.M.E.

[2] Chief Engineer, Quincy Market Cold Storage & Warehouse Co., Boston, Mass. Mem. A.S.M.E.

Correspondence

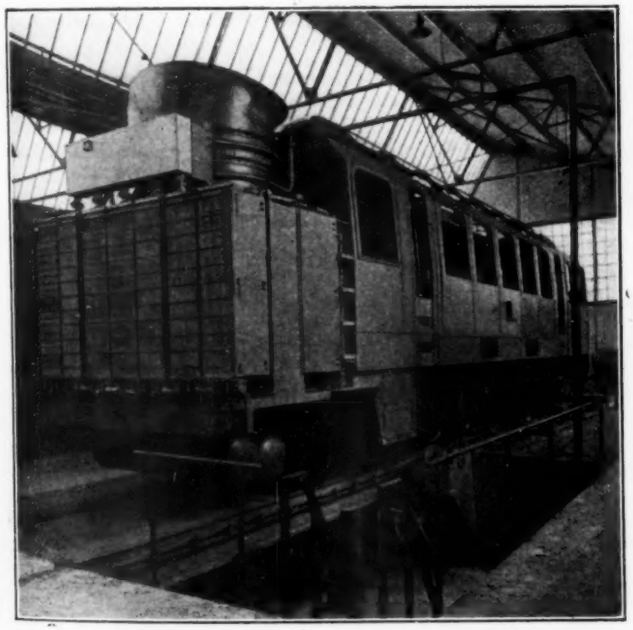
CONTRIBUTIONS to the Correspondence Department of Mechanical Engineering are solicited. Contributions particularly welcomed are discussions of papers published in this journal, brief articles of current interest to mechanical engineers, or comments from members of The American Society of Mechanical Engineers on activities or policies of the Society in Research and Standardization.

The Locomotive Testing Plant

TO THE EDITOR:

On page 881 of MECHANICAL ENGINEERING for November, 1925, in the article by L. H. Fry, it is indicated that locomotive testing plants are of purely American origin and that the author has been unable to find a record of any real testing plant installed outside of the United States

The writer is very far from denying the significance of American achievements in the field of locomotive laboratory tests and especially the remarkable work of his friend Dr. W. F. M. Goss, but for the sake of truth he permits himself to call attention to the fact that the first locomotive laboratory was installed in Kieff in 1882



LOCOMOTIVE TESTING PLANT IN DÜSSELDORF, GERMANY, INSTALLED FOR TESTING LOMONOSSOFF DIESEL-ELECTRIC LOCOMOTIVES

by Alexander Borodin. This laboratory and the classical tests which were carried out there by Mr. Borodin were described in the Proceedings of the Institute of Mechanical Engineers, London, 1886, p. 317.

The laboratory in Kieff was of a temporary character and was abandoned in 1886. But in 1906 another was erected in Leningrad (then St. Petersburg) at the Putiloff Works as a permanent plant on six coupled wheels. Russian railway science is indebted for this to the engineers Smirnoff and Gololoboff. The latter carried out on this plant during the years 1906–1914 numerous tests, some of which have been published in Russian.

In 1912 it became evident that the brakes of the Putiloff plant were not capable of handling modern locomotives, and the following year the Russian Government instituted a new plant at the Alexander Works (now the Proletarian Works) near Leningrad. This plant was intended to serve not only the needs of the Russian railroads but also the pedagogical purposes of the Institute of Ways of Communication. War and revolution, however, delayed its building, and it was not until 1924 that the testing plant began its activities. At the present time tests are being carried out there by Professor Grinenko.

An order from Germany for two Diesel locomotives compelled the writer to erect a temporary Russian testing plant in Esslingen, which was later removed to Düsseldorf. This plant is described in German in his book Die Dieselelektrische Lokomotive (1924), pp. 83–87, in his article in the *Organ für die Fortschritte des Eisenbahnwesens*, 1924, pp. 166–170 and, in English in an article in *The Engineer* of November 14, 1924, p. 553. The accompanying photograph shows the present state of this testing plant, as well as the writer's second Diesel locomotive.

In conclusion the writer is compelled to state that with all the conveniences which locomotive testing plants offer they are not able to replace road tests. This does not refer to trial runs of the usual type, but to scientific tests on sections of a constant profile. This matter has been discussed in the above-mentioned article in the *Organ für die Fortschritte des Eisenbahnwesens*, in the writer's book Lokomotivversuche in Russland, published in 1926 by the Verein deutscher Ingenieure, as well as in numerous articles contributed by him to Russian periodicals.

GEORG LOMONOSSOFF.

Berlin, Germany.

TO THE EDITOR:

May I ask you to allot me a little space in order to enable me to reply to Mr. Fry's criticism of my discussion on his paper which was published in the January, 1926 issue of MECHANICAL ENGINEERING, page 38, and more particularly to items 3 and 4 of his criticism?

In item 3 Mr. Fry simply reiterates his previous statements regarding the efficiency of a multiple-exhaust action, and casts aside, not arguing the point at all, the fact that the three-cylinder locomotives with six exhausts show a better boiler efficiency. In his original paper Mr. Fry himself accentuated the fact that if the latter statement were true, it would contradict one which he considered to be incontestable, namely, that the draft-producing action of the exhaust steam is independent of the intermittency of the exhaust. Of these two facts, Mr. Fry places entire confidence in the latter one, as he thinks that the Purdue and Altoona tests proved it, and is not willing to attach any importance to practical results obtained on three-cylinder simple, and two-cylinder compound, locomotives in this country and abroad, during a period of over 40 years. I can do no better than to add to the practical data presented in my discussion on Mr. Fry's paper, by saying that since writing it an article has been published on three-cylinder locomotives by W. A. Austin, consulting engineer of the Baldwin Locomotive Works, in which he states that as far back as in 1894 a three-cylinder Baldwin-built locomotive exhibited a "mild and even draft on the fire bed," and that a recently built three-cylinder engine showed "an unusually low fuel consumption."[1] As the proportion of the total cylinder volume on the three-cylinder engines was similar to that on two-cylinder engines, the economy could have resulted only from a better efficiency of the boiler (not of the engine) as a sequence of the more uniform exhaust.

To item 4, in which Mr. Fry criticizes the value of road tests, and his statement that "in a road test it is practically impossible to arrange in advance the exact speed and cut-off at which a test shall be run," I would reply that it is always possible to determine the approximate speed at which a locomotive will run at a certain combination of throttle opening and cut-off, using as a basis the data of the previous performance of the locomotive in question in actual service. Moreover, it is absolutely not essential to have the speeds vary by round numbers, for instance, by multiples of 10 m.p.h., or 40 r.p.m., as the ultimate end is to plot curves from the test data, and small deviations one way or another, are of no importance whatsoever. Mr. Fry says, "Very few railroads have a

[1] *Baldwin Locomotives*, January, 1926, pp. 31 and 36.

conveniently situated track on which it would be possible to run an hour's test at 60 m.p.h. at absolutely uniform speed and cut-off." Few as these railroads may be, there is only one, the Pennsylvania, which has a testing plant. Does it mean that no other American railroad should ever attempt to obtain any accurate test data for locomotives? The object of my discussion was to bring to the attention of all these railroads the fact that they are in just as good a position to obtain locomotive test data as if they had a testing plant.

In conclusion, may I refer Mr. Fry and all those who are interested in the "constant-condition road tests" to Mr. G. B. Lebedeff's paper before the International Railway Fuel Association in Chicago, May, 1919, entitled Tests of Locomotives on Russian Railways.[2] During the discussion, Capt. O. S. Beyer, of the University of Illinois, introduced by the chairman as a man who had had a great deal of practical experience in locomotive laboratory tests and in road tests, concluded his remarks by saying:

> The point of the paper was very clearly brought out by the remarks made by my colleague, Professor Snodgrass. It is a matter of technique. The Russians, I think, have the right point of view. Instead of conducting road tests as we conduct them here in the United States, over the entire division, over hill and over dale, taking indicator cards every half-mile or every mile as conditions vary, they confine their test to a portion of the track where the grade condition, the curvature, the speed, etc., as nearly as they can possibly be constant, are constant. That is the significant thing to catch from his paper. If we were to conduct our road tests in the United States in the same way that they conduct them in Russia, I think we would save a great deal of money and a great deal of effort.[3]

This does not mean that a testing plant is of little avail. Many problems can be solved on a testing plant only. No doubt a testing plant gives very reliable and accurate data. As I said in my discussion, I wished to correct the impression which one might obtain from the second paragraph of Mr. Fry's paper that laboratory tests are the only means of studying locomotive performance. Road tests, if properly conducted, offer just as good means for studying locomotive performance.

A. I. Lipetz.[4]

Schenectady, N. Y.

The Earnings of Engineers

To the Editor:

This is written at the risk of criticism from engineers whose ideas of the profession of engineering are more or less altruistic, and is brought forth by my perusal of several articles published in the December, 1925 issue of Mechanical Engineering, principally the article on page 1182 captioned "Earnings and Progress of Graduates." The "conclusions" under this article deal only with improvement in the education and development of engineers; and despite a singularly clear proof on page 1183, Table 3, that they are underpaid, this section of the article, a part of the caption of which is "Earnings," makes no mention of increased remuneration nor of methods of obtaining it.

The publications of the four societies are truly wonderful, showing an attention to engineering development that can elicit nothing but compliment for each issue. But all the societies, and I have the honor to be a member of three of them, have in their zeal for engineering advancement seemingly completely lost trace of the fact that they are composed of engineers; for indeed there are, or should be, two ends for each society: to improve engineering, and to improve the status of engineers. The status of the engineer as far as remuneration goes is fast becoming that of a skilled workman, and unless some radical steps are taken to improve his remuneration he will take his place on a par with the foreman and the skilled workman.

Today I can employ for from $2400 to $3000 a year all the field engineers of six to ten years' experience that I have need for; for $4500 a year, skilled designers of long experience; and competent and heady chiefs of engineering divisions with long experience for $5400 a year. On the other hand, for plasterers brought from the cheaper labor regions of the United States, I must pay $4500 a year; for rigger bosses, $4500 a year; for carpenter foremen, $4500; and for stenographers and secretaries, $2400 to $3360. If they came from the more crowded centers I should have to pay 20 per cent increase on the above prices for the foremen and skilled workmen. Tell me, where does the engineer's superior knowledge and education gain him anything from the standpoint of money return? He designs for, lays out for, directs, and thinks for the foreman and skilled workman. His hours are longer, "as necessary," while the others work eight hours. I am afraid the engineer bids fair to be like the "true scientist" who gives the world his eyes, his health, and all his time and energy, and gains the honor of a charitable burial, a starving widow, and an expensive monument.

It is the duty of the engineering societies with their large and powerful membership to take active steps to improve the remuneration of their profession; and the first step toward this should be the appointment of a joint committee under the guidance of one of our number who has achieved success as an organizer and a doer—to open the subject for a full discussion of the membership and to push it to obtain interest and following.

In conclusion, please understand that my interest is for the underpaid engineer of six or more years' experience, and of course has no selfish note.

H. M. Dougherty.[5]

Vibration Phenomena of a Loaded Unbalanced Shaft while Passing through Its Critical Speed

To the Editor:

In the discussion of the paper on Vibration Phenomena of a Loaded Unbalanced Shaft while Passing through Its Critical Speed, by Mr. E. H. Hull and the writer, which was published in the March issue of Mechanical Engineering, Dr. Paul Heymans suggests that in a more complete treatment of the phenomenon and damping factor should include the internal friction within the shaft or rotor itself. In answer to this, the writer would say that it would not be correct to include this internal frictional force for the reason that it can only arise when the speed of revolution of the plane of deflection of the shaft and the speed of the rotation of the shaft are not the same, that is, in Figs. 1 and 2 (page 251 of the March issue) where *OS* and *SG* revolve at different angular velocities. In the case investigated, however, for a given speed of rotation, an outside fiber of the shaft, which is in tension, remains in tension and an inside fiber, which is in compression, remains in compression as the shaft revolves, so that no energy is dissipated due to a working of the material within the shaft. This equality between the whirling or whipping frequency and the rotational frequency is characteristic of all critical-speed vibration phenomena in revolving shafts. There is a type of shaft vibration, however, which is directly excited by such internal friction, but it can only arise when the speed of rotation of the shaft exceeds its whirling frequency.

For a discussion of this type of vibration by the writer, see the *Philosophical Magazine*, April, 1925, p. 724. See also an article by B. L. Newkirk published in the *General Electric Review*, April, 1924, p. 244.

A. L. Kimball.[6]

Schenectady, N. Y.

Beryllium, a hard white metal, one-third lighter than aluminum and declared to have remarkable properties may find an extensive commercial use as a result of the development of a process for its production at a cost permitting its use as an alloy with aluminum and other light strong alloys. Alloyed with copper, it makes a bronze of extreme hardness and of various brilliant colors. A pound of the metal formerly cost £1000 but now, it is stated, it is being offered at an arbitrary price of £40. However, it is believed that with production facilities on a fair-sized scale, it can be made at £4 per pound. *The Engineer*, Feb. 12, 1926, p. 183.

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[2] Proceedings of the XIth Annual Convention of the I.R.F.A., 1919, pp. 191–227.

[3] Ibid., pp. 236–237.

[4] Consulting Engineer, American Locomotive Co. Mem. A.S.M.E.

[5] Chief Engineer, Chile Exploration Co., Chuquicamata, Chile. Mem. A.S.M.E.

[6] Research Laboratory, General Electric Co. Assoc-Mem. A.S.M.E.

Engineering and Industrial Standardization

International Standardization Conference

THE third informal international standardization conference of the chairmen and secretaries of the nineteen national standardizing bodies will be held in the Engineering Societies Building, New York, beginning April 13. The first of these conferences was held in London, England, in 1921, and the second in Zurich, Switzerland, in 1923. Between these conferences M. Zollinger, Secretary of the Commission de Normalization du V. S. M., Switzerland, has acted as temporary secretary and as such has assisted in the interchange of correspondence between the several organizations.

As part of the business of the New York meeting a proposal to set up an international standardization organization with a permanent secretary will be presented and thoroughly discussed. One of the principal functions of such an international organization would be to facilitate the interchange of information and coöperative study of problems of standardization.

The Executive Committee of the American Engineering Standards Committee has carefully considered this question and, through the acceptance of a report of its Committee on Foreign Coöperation, has indicated its approval of such an organization provided a satisfactory constitution and scope of activities can be agreed upon.

Timely Notes

Symbols and Abbreviations. In the November, 1925, issue of MECHANICAL ENGINEERING, notice was given of the organization of a new Sectional Committee on Scientific and Engineering Symbols and Abbreviations. The sponsors for this project include the American Association for the Advancement of Science, the American Institute of Electrical Engineers, the American Society of Civil Engineers, The American Society of Mechanical Engineers, and the Society for the Promotion of Engineering Education.

On January 21 this Sectional Committee held its first meeting, which was very largely attended. The personnel list, copies of which have been recently distributed by the American Engineering Standards Committee, indicates that the Committee now numbers twenty-four members, representing thirty organizations. The officers of the Committee who were elected at this meeting are as follows: Chairman, J. Franklin Meyer, Bureau of Standards, Washington; Vice-Chairman, Sanford A. Moss, Thomson Research Laboratory, General Electric Co.; Secretary, Preston Millar, General Manager, Electrical Testing Laboratories, New York; Assistant Secretary, S. McK. Gary, Electrical Testing Laboratories, New York.

The scope of this project approved at the meeting is as follows:

> "A broad program of unification of graphical symbols, and symbols for quantities in equations and formulas, and of abbreviations, as used in engineering and scientific reports, tables, publications, etc., but not including definitions of terms used in engineering and scientific practice."

Gib-Head and Plain Taper Keys. The report of Sub-Committee No. 4 on Gib-Head and Plain Taper Keys was completed recently and blueprint copies of the proposed standards were submitted to the members of the Sectional Committee on the Standardization of Shafting for study. It was then discussed at a meeting of the Sectional Committee on Tuesday, March 9. The Sectional Committee recommended certain slight revisions and instructed the secretary to distribute it for criticism and comment in proof form.

Steel Flanges and Flanged Fittings. The report of Sub-Committee No. 3 on Steel Flanges and Flanged Fittings was revised at a three-day session of this Committee held last December. New drafts have been submitted to the members of this sub-committee for their approval, after which it will be sent to the Sectional Committee on Pipe Flanges and Flanged Fittings for discussion at a meeting and followed by letter ballot.

Pins and Washers. At the request of the Society of Automotive Engineers and on the approval of the A.S.M.E., the A.E.S.C. has recently granted the former joint sponsorship for two committees which are to develop standards for the various kinds of machine pins and plain and lock washers.

Last August, in its capacity as sole sponsor, the A.S.M.E. issued the invitations to the coöperating bodies and received acceptances for ten organizations and Government departments. Accordingly, the organization meetings of these committees were held on the morning and afternoon of March 19, respectively.

Track Bolts. The report of Sub-Committee No. 4 on Track Bolts and Nuts is now in printer's proof form and is in the hands of the members of that sub-committee for approval. In this form the American Railway Association, Engineering Division, reviewed it at its March 8–13 meeting in Chicago.

Wrench-Head Bolts and Nuts. The finally revised report of Sub-Committee No. 2 on Wrench-Head Bolts and Nuts was mailed in February to the members of the Sectional Committee on the Standardization of Bolt, Nut, and Rivet Proportions in printer's proof form for letter ballot.

Tool Holders and Tool-Post Openings. Satisfactory progress has been made toward the completion of the standard for Tee Slots, so the Central Committee on the Standardization of Small Tools and Machine-Tool Elements has for the past three months been developing the personnel of the sub-committee which is to undertake the standardization of Tool Holders and Tool-Post Openings. The replies to the invitations extended to coöperating bodies for the appointment of representatives having been received, the sponsors and the Central Committee called this new sub-committee together on March 25 for organization. The meeting was a successful one and the sub-committee believes that shortly it will be able to distribute a tentative draft of the proposed standard.

Anglo-American Conference on Screw Threads

IN THE Foreword to its report on Screw Threads for Bolts, Machine Screws, Nuts, and Commercially Tapped Holes, the Sectional Committee on the Standardization and Unification of Screw Threads made the following statement:

> Though its third purpose has not yet been attained, the Sectional Committee hopes that further steps may be taken by mutual concessions which will result in bringing together the Whitworth and the American systems of threads so as to insure interchangeability in the English-speaking world. The Committee also looks forward to the time when, by conference with the standardization associations of the countries using the metric system, agreements along similar lines for fits and tolerances for metric threads will be brought about.

Since April, 1924, when this report was issued, the A.S.M.E. and the S.A.E., the sponsor bodies for this Sectional Committee, and the A.E.S.C. have carried on a general correspondence with British, Canadian, and Australian standards associations on this subject.

When plans were being developed for the third conference of the chairmen and secretaries of the national standardizing bodies, the American Engineering Standards Committee, on the recommendations of the sponsors of the Sectional Committee on the Standardization and Unification of Screw Threads and jointly with the National Screw Thread Commission, invited the British, Canadian, and Australian standards associations to send representatives to the United States in April for the purpose of discussing the possibility of reaching a compromise on the principal differences which now exists between the Whitworth system and the American (National) Standard system of screw threads.

Our British friends having accepted this invitation, plans are now being completed for this conference. On the nomination of the National Screw Thread Commission, the Society of Automotive Engineers and The American Society of Mechanical Engineers, C. E. Skinner, Chairman of the A.E.S.C., has appointed a Committee on Agenda for this conference which consists of Luther D. Burlingame, Chairman, and Earle Buckingham, Edwin H. Ehrman, Ralph E. Flanders, and Eugene C. Peck.

Test Code on Instruments and Apparatus

Preliminary Draft of Chapter 3, Temperature Measurement, Part 2—Glass Thermometers

THE Main Committee on Power Test Codes takes pleasure in presenting to the members of the Society for criticism and comment Chapter 3 of the Code on Instruments and Apparatus, dealing with the first half of the Chapter 3, Part 2, on Glass Thermometers, Temperature Measurements. The Individual Committee which developed this draft consists of Messrs. C. F. Hirshfeld, Chairman, C. M. Allen, E. G. Bailey, L. J. Briggs, W. A. Carter, J. D. Davis, R. E. Dillon, F. M. Farmer, J. J. Flather, J. B. Grumbein, O. Monnett, S. A. Moss, R. J. S. Piggott, E. B. Ricketts, and S. W. Sparrow.

Code No. 19 on Instruments and Apparatus will consist of twenty-two chapters dealing with the following subjects: (1) General Considerations,[1] (2) Pressure Measurement (7 sections), (3) Temperature Measurement[2] (11 sections), (4) Head Measurement, (5) Quantity of Material, (6) Electrical Measurements, (7) Mechanical Power, (8) Indicated Horsepower, (9) Heat of Combustion, (10) Chemical Composition, (11) Quality of Steam, (12) Time, (13) Speed, (14) Mechanical Measurements, (15) Surface Area, (16) Density, (17) Viscosity, (18) Humidity, (19) Concentration of Dilute Solutions, (20) Smoke, (21) Condenser Leakage,[3] (22) Hydraulic Power Plants.

The Individual Committee, the Main Committee, and the Society will welcome suggestions for corrections or additions to this draft from those who are especially interested in this subject. These comments should be addressed to the Chairman of the Committee in care of The American Society of Mechanical Engineers, 29 West 39th Street, New York, N. Y.

GENERAL

Measurement of temperature is generally supposed to be one of the simplest and most accurate measurements performed in engineering. This is decidedly a misconception. Accurate temperature measurement under some conditions is impossible with our present knowledge. Under many of the conditions met in power tests the desired accuracy in the measurement of temperature can be obtained only by observance of suitable precautions in the installation and use of temperature-measuring instruments, and in the interpretation of the results obtained with them. In some cases an arbitrarily standardized method is prescribed in the code, and it is to be followed in making temperature measurements under such conditions.

Many of the instruments available for temperature measurement are capable of indicating temperature far more accurately than required in most of the tests considered in the code. The difficulty comes in the use of the instruments, due either to the manner in which they are installed or the manner in which they are used after installation. Specific directions and precautions in the use of the various types of temperature-measuring instruments are given in later paragraphs devoted to the individual instruments. Specific directions for the measurement of temperature of certain materials such as superheated steam, flue gas, exhaust gas from internal-combustion engines, etc., are given under individual headings at the end of this chapter. Certain general considerations which are of wide application are treated here.

One of the principal sources of error in temperature measurement is the natural tendency toward temperature equalization. This tendency which causes the flow of heat from regions of higher to regions of lower temperature must always be borne in mind, and the effect of any possible flow on the reading of the instrument must be determined in some way before any assurance of accuracy can be had. Examples of the ways in which this tendency may influence results are given in the paragraphs immediately following.

Assume a thermometer well inserted in the wall of a pipe as shown in Fig. 1 (see MECHANICAL ENGINEERING, December, 1925, p. 116), and assume that some material, such as superheated steam or a highly heated gas, is flowing in the pipe. It is commonly assumed that the thermometer well acquires the temperature of the flowing material and therefore, that if it is partly filled with liquid and a thermometer is inserted therein, a correct measurement of the temperature of the flowing material will be obtained.

GENERAL DESCRIPTION AND CLASSIFICATION

1 Temperature-measuring instruments of this type depend upon the expansion of a liquid within a closed receptacle. A capillary glass tube, generally referred to as the "stem," is closed at one end, and terminates at the other end in a spherical or cylindrical enlargement known as the "bulb." The bulb and a portion of the stem (the bore or capillary) are filled with mercury or some other suitable liquid, the remaining part of the bore being filled with the vapor of this liquid or with this vapor mixed with an inert gas. The stem is graduated, and readings of the temperature are obtained by noting the position of the end of the liquid column when the instrument is immersed in the medium the temperature of which is being measured.

2 Limits of application and use are set by the minimum temperature at which the expanding fluid can be used; by the maximum temperature which glass can stand; by the fact that the instrument must be at least partly immersed in the material the temperature of which is to be measured; and by the fact that it must be read *in situ*.

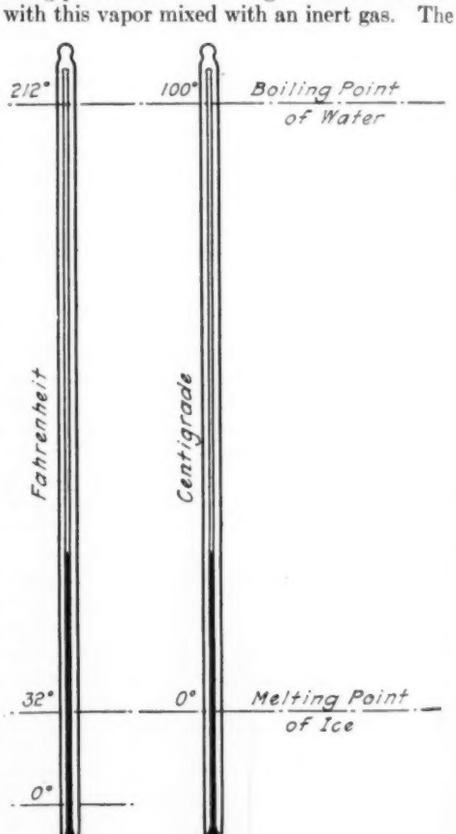


FIG. 5 COMPARISON OF THERMOMETER SCALES IN GENERAL USE

3 A glass thermometer can be characterized according to its scale, expanding fluid, form, kind of glass, and immersion. These characteristics are discussed separately in the following paragraphs.

SCALE

4 There are in general use two thermometer scales known as the fahrenheit and the centigrade. A comparison of these scales is shown in Fig. 5.

In the fahrenheit scale the interval between the fixed points, i.e., the boiling and freezing points of water at an absolute pressure of 29.92 in. of mercury at the temperature of melting ice and under standard gravity conditions, is divided into 180 equal parts; the boiling point is marked 212, and the freezing point is marked 32. In the centigrade scale the interval between the fixed points is divided into 100 equal parts; the boiling point is marked 100, and the freezing point is marked 0. Each of the 180 or 100 divisions in the respective scales is called a "degree." The reading for a given temperature on one scale may be changed to the correspond-

[1] This chapter was published in the February, 1923, issue of MECHANICAL ENGINEERING.

[2] Part 1 of chapter 3, called Temperature Measurement, was published in the December, 1925, issue of MECHANICAL ENGINEERING.

[3] This chapter was published in the November, 1925, issue of MECHANICAL ENGINEERING.

ing reading on the other scale by use of one of the following formulas:

$$F = 9/5\,C + 32$$

$$C = 5/9\,(F - 32)$$

where F = degrees fahrenheit (°F.)
C = degrees centigrade (°C.).

Tables for converting temperatures from one scale to the other are given in the Smithsonian Meteorological Tables, which may be obtained from the Smithsonian Institute, Washington, D. C.

EXPANDING FLUID

5 Mercury, alcohol, toluene, and pentane are the liquids generally used in liquid-in-glass thermometers. The lower limit of the temperature range through which each liquid may be used is determined by its freezing point. The boiling point is dependent upon the pressure on the liquid, and in thermometry the temperature range is often extended by introducing an inert gas such as nitrogen into the capillary space above the liquid, thus increasing the pressure on the liquid. The freezing points and boiling points of the above-named liquids under a pressure of a standard atmosphere are approximately as given in Table 2.

TABLE 2 FREEZING AND BOILING POINTS OF LIQUIDS USED IN GLASS THERMOMETERS

	Freezing point deg. fahr.	Boiling point,[1] deg. fahr.
Mercury	−38	+678
Ethyl alcohol	−170	+173
Toluene	−134	+231
Pentane	−203	+97

[1] The actual boiling point of the liquid in the thermometer will be higher than the tabulated value at one atmosphere due to increased pressure in the tube above the liquid as it expands and the temperature of the gas above the liquid increases.

Mercury is much superior to the other liquids for use in liquid-in-glass thermometry for temperatures above its freezing point. Mercury has a lower coefficient of expansion than the other liquids mentioned, which at first sight appears to be a disadvantage. But this is more than offset by the corresponding reduction in the emergent-stem correction and by the fact that mercury does not wet the walls of the capillary, which permits the use of a capillary tube of smaller bore. This in turn makes it possible to decrease the volume of the bulb so that in spite of its low expansion coefficient it is possible to secure in a mercury thermometer an "openness of scale" which is equal to or greater than that obtained with other liquids. Mercury also has a high thermal conductivity which facilitates the distribution of heat in the bulb, and its opaqueness makes the thermometer easier to read. The other liquids are transparent and colorless, but may be colored.

FORM

6 The term "form" as used in describing thermometers refers to their physical make-up, and particularly to the location of the graduations, the assembly, and the shape of the device.

7 Some glass thermometers have the graduations engraved on the glass stem of the thermometer. Such thermometers are commonly known as "engraved-stem" thermometers (sometimes incorrectly called "chemical" thermometers). Engraved-stem thermometers are sometimes protected from breakage by an armor of metal or other material. If a thermometer is protected in this manner it is known as an "engraved-stem armored thermometer." Fig. 6 shows two engraved-stem unarmored thermometers, and Fig. 7 shows one with armor.

8 Figs. 8 and 9 show two types of enclosed-scale thermometers. In each type the glass scale and capillary tube are contained within a closed glass tube, one end of which is attached to the bulb. The one shown in Fig. 8 is used for the same service as an ordinary engraved-stem thermometer. Fig. 9 represents a Beckmann differential thermometer, which is unique in that its range can be shifted by displacing part of the mercury into a reservoir at the top. This is used in calorimeters where a thermometer of short range and one that is capable of being read to a small fraction of a degree is required. By the use of a low-power telescope it is possible to read these thermometers to 0.001 deg. cent. Thermometers of this type have a large time lag, and it is necessary to make allowance for this in some cases. In calorimetric work it is also necessary to allow for the heat capacity of the immersed portion of the thermometer. The range of the thermometer may be adjusted as required. The length of the scale is generally equivalent to 5 deg. cent., and is arbitrarily numbered from 0 to 5.

A chamber is provided at the top of the thermometer to accommodate the part of the mercury that is not required; and by expelling the excess mercury into the chamber the zero of the scale may be adjusted to correspond to any temperature over a wide range. The value of each scale division varies with the amount of mercury in the bulb and the bore up to the zero of the scale, and allowance has to be made for this. The thermometer is said to have a given setting, for instance 20 deg. cent., if its scale reading is 0 deg. when the temperature of the bulb is 20 deg. cent. Table 3, calculated for thermometers of Jena 16^{III} or Corning Normal glass, gives a series of factors corresponding to different settings by which

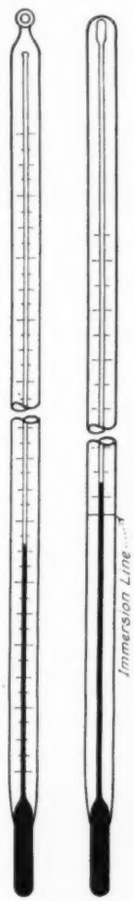


FIG. 6 GOOD TYPES OF ENGRAVED-STEM THERMOMETER

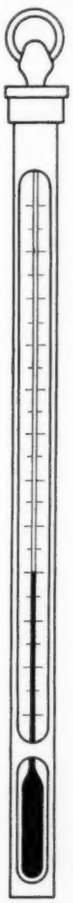
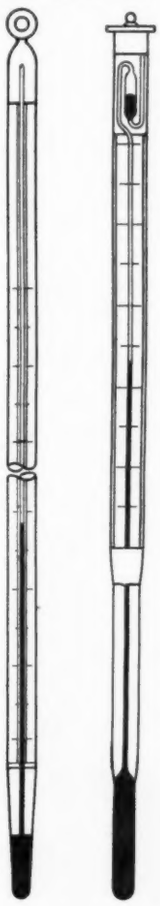


FIG. 7 ARMORED THERMOMETER



FIGS. 8 AND 9 TWO TYPES OF SEPARATE ENCLOSED-SCALE THERMOMETERS

each observed temperature difference must be multiplied. This factor is made unity for a setting of 20 deg. cent.

TABLE 3 FACTORS CORRESPONDING TO DIFFERENT SETTINGS

Setting deg. Cent.	Factor	Setting deg. Cent.	Factor
0	0.9931	55	1.0094
5	0.9950	60	1.0105
10	0.9968	65	1.0115
15	0.9985	70	1.0125
20	1.0000	75	1.0134
25	1.0015	80	1.0143
30	1.0029	85	1.0152
35	1.0043	90	1.0161
40	1.0056	95	1.0169
45	1.0069	100	1.0177
50	1.0082		

In most work for which this type of thermometer is suited a knowledge of the individual temperature to a high degree of accuracy is not required, but the difference between two temperatures is desired to a high degree of accuracy. Thus a very exact determination of the temperature corresponding to the zero setting is not required.

9 A distinctly different form, commonly known as the "in-

dustrial thermometer," has the glass thermometer built into a frame with a metal back in such a way that its lower end is contained within a metal bulb. Graduations are carried on the metal back and not on the glass stem of the thermometer itself. This type of thermometer is characterized by large and distinct figures for the graduation marks and threaded connections for quickly and securely installing the thermometers. Such thermometers are often used with a special thermometer well known as a "separable socket." This socket screws into the container and the metal bulb of the thermometer then fits into the socket, making it possible to remove the thermometer without leaving an opening in the wall of the container. Fig. 10 shows a thermometer of the industrial type, which may be designated as "straight-type industrial thermometers" to distinguish them from others referred to below.

Fig. 11 shows an angle thermometer of the industrial type. Fig. 12 shows an industrial-type thermometer with a wooden back, which is usually called the "floating type" of industrial thermometer. In Fig. 13 various types of thermometer wells are shown.

GLASS

10 The glass employed for the construction of a thermometer must be chosen with regard to several characteristics. The main considerations are that the glass shall rapidly return to the normal

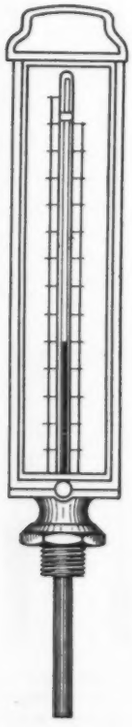


FIG. 10 STRAIGHT-TYPE INDUSTRIAL THERMOMETER

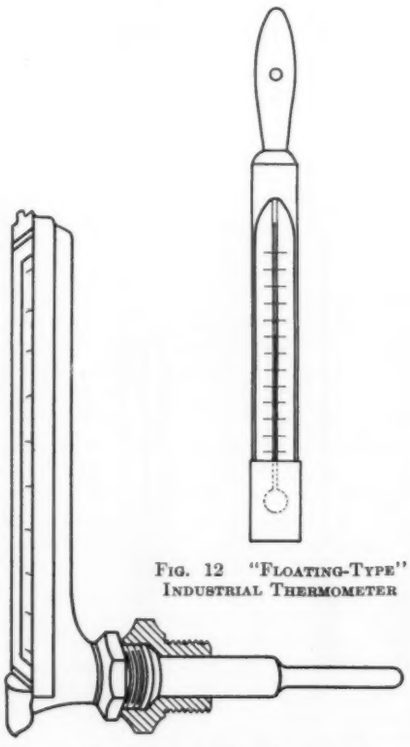


FIG. 11 ANGLE-TYPE INDUSTRIAL THERMOMETER

FIG. 12 "FLOATING-TYPE" INDUSTRIAL THERMOMETER

state after being exposed to a change of temperature, and furthermore that it shall be stable. The first condition is never exactly realized in practice, for if the ice point be accurately determined before and after exposure to a change of temperature, it will be noted that the two determinations do not exactly correspond.[4]

11 A brief description of some of the most common glasses used in construction of thermometers follows.

a "English Crystal" glass and also "Kew" glass, which were in use for many years, were lead-potash glasses which contained a small proportion of soda. These glasses have since been superseded for precise work by later types, but lead glass is still employed for the construction of cheaper glass thermometers due mainly to its soft nature and good working properties.

b "Jena 16III" is a soda-lime glass containing zinc oxide and alumina. This glass has had a very widespread use in the construction of thermometers of ordinary and medium range. Tubes made of this glass are characterized by a thin purple line throughout their length.

[4] See Pars. 44–52 for further discussion of shifting of ice point and means of reducing it to a minimum.

c "Jena 59III" is used for work at higher temperatures, and is a hard glass of borosilicate, the principal ingredients of which are soda, boric oxide, and alumina.

d The Corning "normal" and borosilicate glasses are copies respectively of Jena 16III and 59III and are made in America by the Corning Glass Company. Most American thermometers are now made of Corning glass.

e Combustion tubing, pyrex glass, and fused silica are used in making thermometers for measuring high temperatures.

IMMERSION

12 Thermometers may be graduated to indicate correctly for total immersion, that is, immersion of bulb and stem up to the

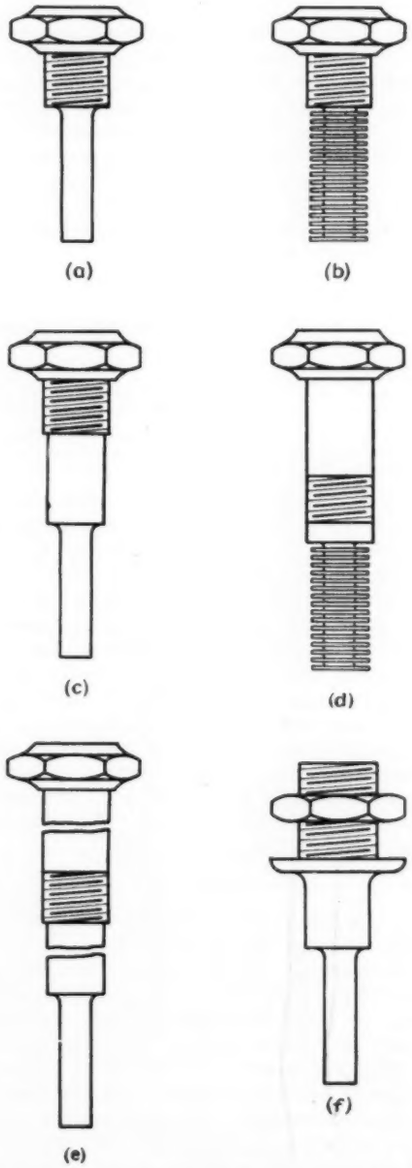


FIG. 13 VARIOUS TYPES OF THERMOMETER WELLS

point reached by the expanding liquid in the thermometer. Partial-immersion thermometers are graduated to indicate correctly for a certain definite immersion, such as 3 inches, and with that part of the stem which projects at some other temperature such as room temperature. An "emergent-stem correction" must be made when a thermometer in use has a portion of the stem at a temperature other than that which it had during calibration, or when a greater or lesser portion of the stem is immersed in the medium, the temperature of which is being determined. This is necessary because the temperature of the stem and of the column of fluid (and therefore the height of the column) is different from that existing during calibration. See Par. 21 for the corrections to be applied.

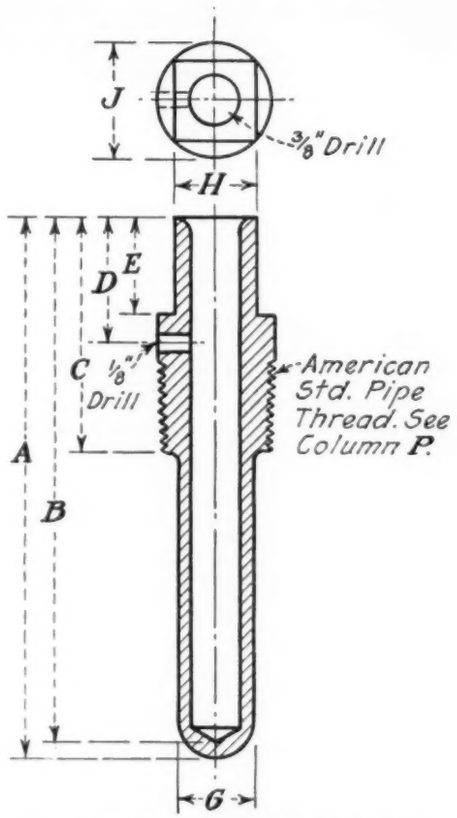


FIG. 14 DETAILS OF PLAIN THERMOMETER WELLS SUITABLE FOR USE IN LIQUIDS AND SATURATED VAPORS
(See Table 5 for dimensions. F = length of pipe thread.)

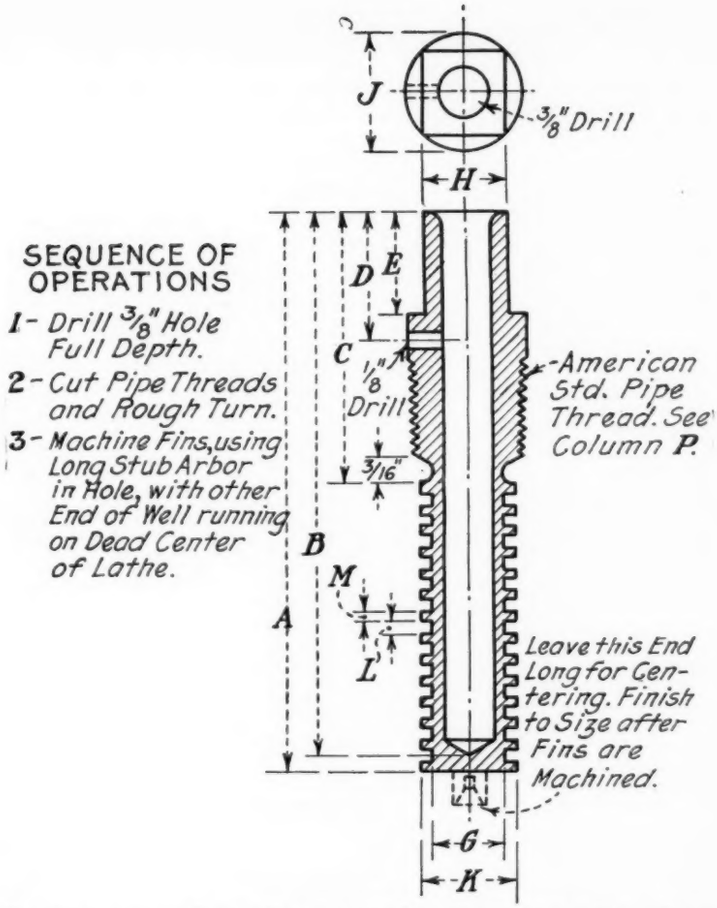


FIG. 15 DETAILS OF FINNED THERMOMETER WELLS SUITABLE FOR USE IN GASES AND SUPERHEATED VAPORS
(See Table 6 for dimensions. F = length of pipe thread; N = number of fins; O = number of grooves.)

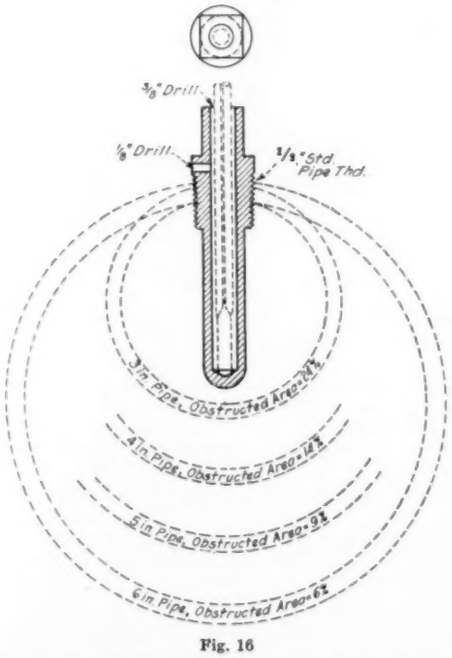

3/8" Drill
1/8" Drill
1/4" Std. Pipe Thd.
3 in Pipe, Obstructed Area=14%
4 in Pipe, Obstructed Area=10%
5 in Pipe, Obstructed Area=8%
6 in Pipe, Obstructed Area=6%

Fig. 16

FIGS. 16 AND 17 METHOD OF INSTALLING PLAIN THERMOMETER WELLS IN CIRCULAR PIPE

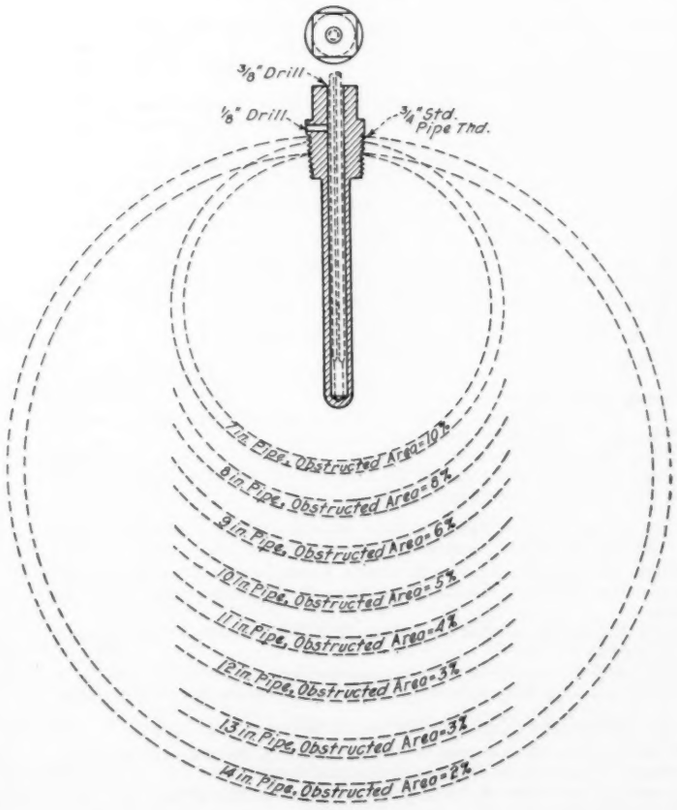

3/8" Drill
1/8" Drill
1/4" Std. Pipe Thd.
7 in Pipe, Obstructed Area=10%
8 in Pipe, Obstructed Area=8%
9 in Pipe, Obstructed Area=6%
10 in Pipe, Obstructed Area=5%
11 in Pipe, Obstructed Area=4%
12 in Pipe, Obstructed Area=3%
13 in Pipe, Obstructed Area=3%
14 in Pipe, Obstructed Area=2%

Fig. 17

RANGE AND ACCURACY

13 The accuracy which can be expected with engraved-stem unarmored thermometers with total immersion is given in Table 4.

INSTALLATION

(See "General—Installation," Pars. 14 to 21, inclusive, Chap. I.)

14 Before and after calibrating a thermometer previous

to its installation a careful examination should be made of the column of the liquid to ascertain if it is separated or if the gas is occluded. A reading glass is often found helpful in making such an examination. There are four operations employed in manipulating thermometers to rejoin the mercury which has become separated or to remove a gas bubble from the bulb: namely, (*a*) warming, (*b*) cooling, (*c*) tapping on the end, and (*d*) tapping on the side of the thermometer. Extreme care should be exercised in carrying glass thermometers of all forms. The stem should always be carried right side up and the greatest possible freedom from excessive vibration or jarring should be provided for. Neglect in this respect may vitiate the results of most careful calibration, as it may cause the mercury column to separate.

The U. S. Bureau of Standards Circular No. 8, Testing of Thermometers, Section 15 (2nd edition) gives the following instructions for manipulating the mercury within the capillary tube:

a Warming the bulb of a thermometer may be done in water or oil or in the air high above a gas or alcohol flame, but great care must be taken, especially with high-temperature thermometers, not to heat the bulb to a temperature higher than the thermometer is intended to measure. The upper end of a thermometer stem may be warmed over a bunsen burner if this is done very gradually. When the thermometer is warmed over a flame, it should be rotated about its axis.

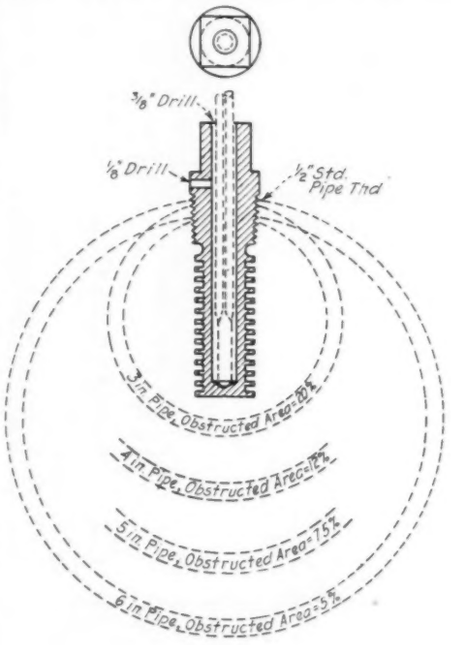

3/8" Drill
1/8" Drill
1/2" Std. Pipe Thd
3 in Pipe, Obstructed Area=20%
4 in Pipe, Obstructed Area=15%
5 in Pipe, Obstructed Area=7.5%
6 in Pipe, Obstructed Area=5%

Fig. 18

b Cooling may be accomplished in cold water, ice, a freezing mixture, or CO_2 snow, but such cooling should not be attempted while the thermometer bulb is still hot to the touch.

c Tapping or striking a thermometer on the end must be done carefully at all times, and much more so when the bulb is only partly filled with mercury and the thermometer is inverted. This tapping may be "soft," as when the thermometer is held vertically in the hand and the hand (not the thermometer) is struck on the table, or it may be "sharp," as when the thermometer is held vertically and struck downward on a pad of paper.

d Tapping on the side of a thermometer may be done "softly" with the hand or "sharply" with a pencil. Either must be done with care, as there is danger of breaking the stem. Different thermometers require different treatment, but the following procedure may serve as a guide in the manipulation of thermometers not filled with gas under pressure.

To remove mercury from upper bulb when it is partly full:

Hold thermometer vertically, bulb down.

Tap "softly" on side near the top and "softly" on end, to bring mercury to lower part of upper reservoir.

Then try both tapping "softly" and "sharply" on end, and if this fails to bring the mercury down the stem—

Warm the bulb until mercury rises and unites with that in the reservoir.

Cool very slowly and probably the mercury will all come down.

If not, try again, cooling more slowly.

To remove mercury from upper reservoir when this is completely full or when mercury persistently stays at the top of reservoir:

Warm the upper end carefully over a Bunsen flame, beginning at the extreme tip. Mercury will be driven down the capillary by its own vapor pressure.

If small mercury globules are left, warm a little more and they will condense farther down.

Wait until the upper end cools to a temperature comfortable to the hand.

Warm the lower bulb until mercury rises and collects the small globules.

To find whether there is any residual gas in the thermometer bulb:

Warm the bulb until at least a few centimeters of mercury appear in the capillary; if mercury is already there, do not warm.

Invert the thermometer and see whether mercury runs down.

If not, there is probably no gas in the bulb.

TABLE 4 ACCURACY TO BE EXPECTED FROM ENGRAVED-STEM UNARMORED THERMOMETERS WITH TOTAL IMMERSION

Range,[1] deg. fahr.	Subdivision deg. fahr.	Accuracy of commercial thermometers as purchased deg. fahr.	Variance of calibrated thermometers,[2] deg. fahr.
— 38 to 575	2	2 to 5	1 to 2
— 38 to 1000	5	5 to 10	2 to 10
—300 to 70	2	2 to 5	0.5 to 2
212 to 400	5	2	1
	2	1	0.5
	1 or 0.5	1	0.2
400 to 600	5	2	1
	2	2	0.5
	1	1	0.2
600 to 800	5	3	2
	2	2	1
800 to 1000	5	5	2
	2	4	2

[1] See Par. 13, Chap. I, for types applicable to different temperature ranges.
[2] See discussion of variance in Pars. 13 to 16, inclusive, Chap. II.

If mercury runs down, let it run a few centimeters and look for a bubble in the bulb.

Right the thermometer and see whether this bubble entirely disappears when the mercury returns to the bulb. If this bubble disappears, no significant amount of gas is present.

To remove gas when found:

Invert thermometer and run some mercury into the capillary.

Right thermometer and tap "sharply" on side and on end to bring gas to the top of bulb before mercury all returns.

Cool bulb as much as possible, tapping "sharply" on end when cold.

Invert thermometer and tap very "softly" on end to bring down mercury, which is still separated by the air bubble from that in the bulb.

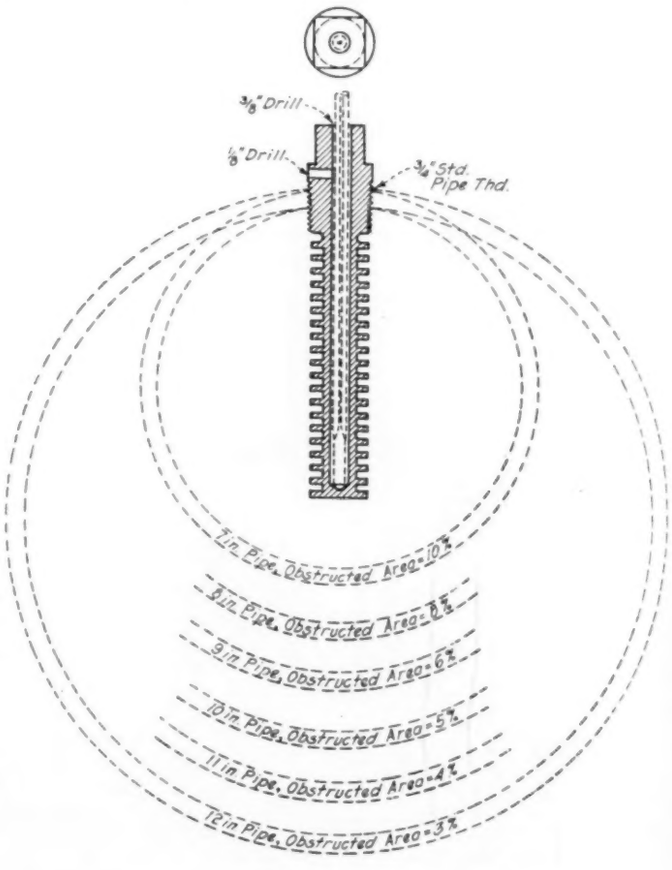

3/8" Drill
1/8" Drill
3/8" Std. Pipe Thd
1 in Pipe, Obstructed Area=10%
3 in Pipe, Obstructed Area=8%
3 in Pipe, Obstructed Area=6%
10 in Pipe, Obstructed Area=5%
11 in Pipe, Obstructed Area=4%
12 in Pipe, Obstructed Area=3%

Fig. 19

When this has come down, either tap "sharply" or warm to bring down the mercury from the bulb, but do not let the separated thread get into the upper bulb until the main mercury column is ready to join it.

Get the two separated parts to join in any convenient enlargement or in the upper reservoir.

Right the thermometer or hold it at an angle, with the top higher, and let the mercury run slowly into the bulb, watching carefully the point where the bubble is left, to be sure that the column does not separate.

If the bubble begins to enlarge, run the mercury more slowly.

To remove bubbles from high-temperature thermometers:

Bubbles can often be removed, even from high-temperature thermometers, which are filled under pressure, provided there is an enlargement in the stem (e.g., between the 0 and the 600 deg. fahr. mark).

If there is no such enlargement, the gas can sometimes be removed by

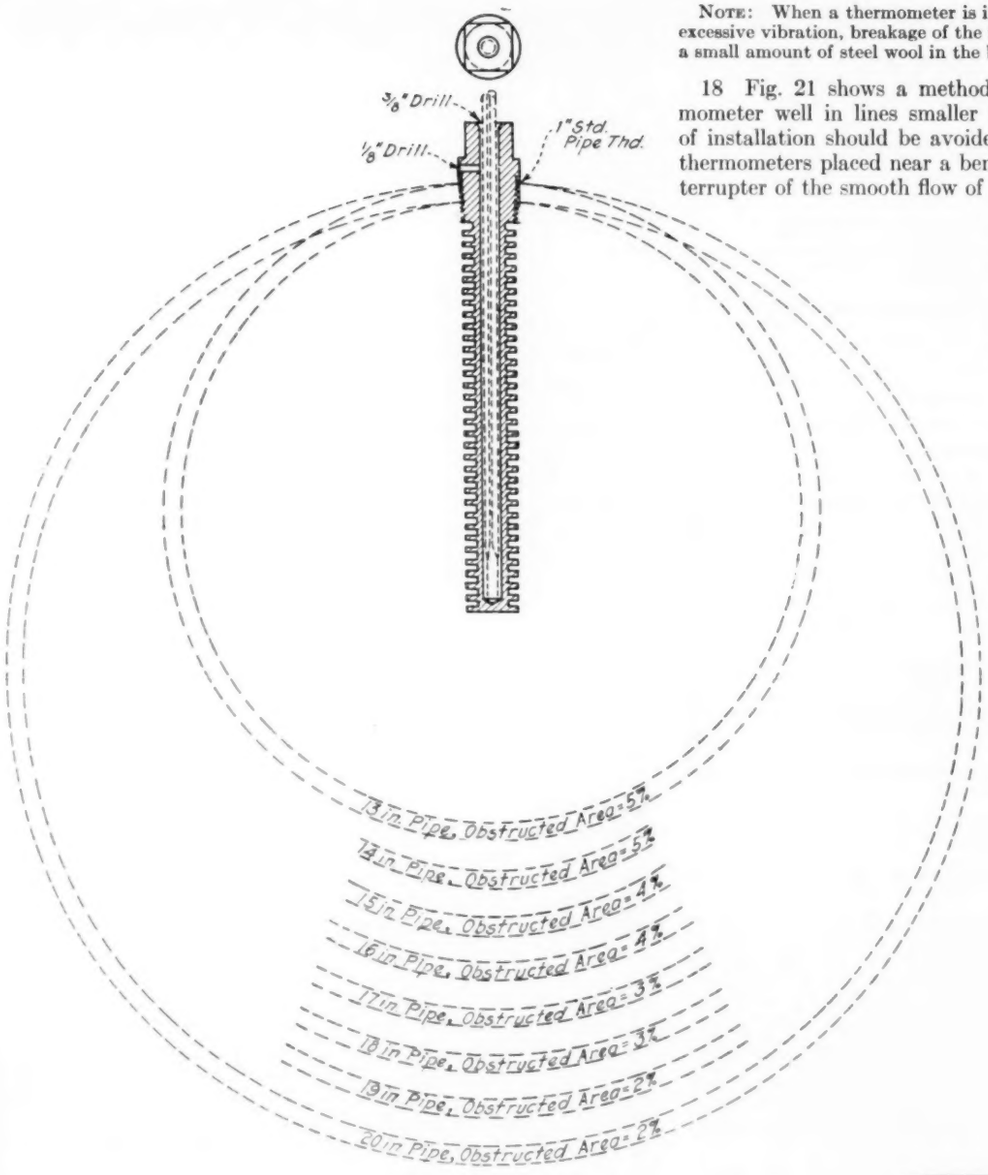

3/8" Drill
1/8" Drill
1" Std. Pipe Thd.
3 in Pipe, Obstructed Area = 5%
4 in Pipe, Obstructed Area = 5%
5 in Pipe, Obstructed Area = 4%
6 in Pipe, Obstructed Area = 4%
7 in Pipe, Obstructed Area = 3%
8 in Pipe, Obstructed Area = 3%
9 in Pipe, Obstructed Area = 2%
10 in Pipe, Obstructed Area = 2%

Fig. 20

FIGS. 18, 19, AND 20 METHOD OF INSTALLING FINNED THERMOMETER WELLS IN CIRCULAR PIPE

long-continued sharp tapping on the end, or sometimes by freezing the mercury by means of CO_2 snow, then warming the bulb (from the bottom) rapidly against the hand. Mercury will not break the bulb on freezing, as it does not expand.

15 *Thermometer Wells* are of two classes, as discussed in Part I, Par. 17.

16 The dimensions of plain wells, which are suitable for use in liquids and saturated vapors, are standardized in Table 5, and Figs. 14, 16, and 17.

TABLE 5 DIMENSIONS FOR PLAIN THERMOMETER WELLS (Inches)

Pipe size, (inches)	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*J*	*P*
3–6	3 15/16	3 11/16	1 9/16	11/16	1/2	7/8	5/8	5/8	7/8	1/2
7–20	7 1/16	6 3/4	1 15/16	11/16	1/2	1 1/16	3/4	5/8	1 1/16	3/4

TABLE 6 DIMENSIONS OF FINNED THERMOMETER WELLS (Inches)

Pipe size, (inches)	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*J*	*K*	*L*	*M*	*N*	*O*	*P*
3–6	3 21/32	3 9/16	2 9/16	1 3/8	1/2	3/4	0.525	5/8	7/8	11/16	3/32	1/16	14	13	1/2
7–12	6 11/16	6 9/16	2 13/16	1 5/8	1/2	3/4	5/8	3/4	1 1/16	7/8	5/32	3/32	20	19	3/4
13–20	9 7/8	9 3/4	2 13/16	1 5/8	1/2	3/4	5/8	1	1 5/16	1 1/8	5/32	3/32	33	32	1

17 The dimensions of finned wells, which are suitable for use in gases and superheated vapors, are standardized in Table 6, and Figs. 15, 18, 19, and 20.

NOTE: When a thermometer is installed in a well which is subjected to excessive vibration, breakage of the thermometer can be avoided by placing a small amount of steel wool in the bottom of the well.

18 Fig. 21 shows a method of installing the small-size thermometer well in lines smaller than 3-inch. However, this type of installation should be avoided in steam lines when possible as thermometers placed near a bend, converging section, or other interrupter of the smooth flow of steam are apt to read an incorrect temperature because of the throttling and separating effects of the obstruction. When using this type of installation on small lines (smaller than 3-inch) the tee should be one pipe size larger than the line.

PRECAUTIONS

19 When using a glass thermometer it should not be lifted out of the medium the temperature of which is being measured, or out of the thermometer well while the reading is being taken. The magnitude of the error which can be caused in this way depends upon the temperature difference between the material the temperature of which is being measured and the air surrounding the thermometer when removed from this material or from the well. An idea of the magnitude of the possible error can be gained from the following. Experiment has shown an error of 32 deg. fahr. when withdrawing a glass thermometer from a flue containing gas at 600 deg. fahr. and reading after withdrawal. The same thing in the case of an armored thermometer gave an error of about 13 deg. fahr. due to the fact that the armor contained sufficient heat to materially decrease the rate at which the liquid in the thermometer cooled.

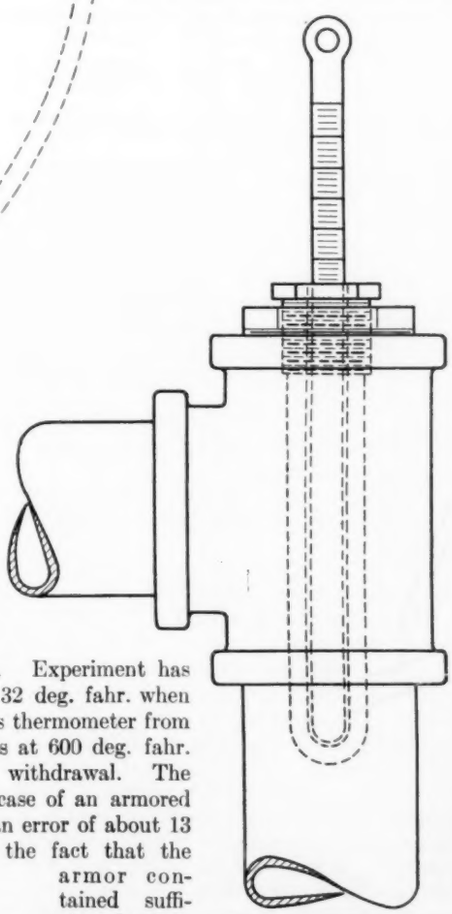


FIG. 21 METHOD OF INSTALLING THERMOMETER WELLS IN PIPE LINES SMALLER THAN THREE INCHES

20 Care should also be taken to avoid parallax, by having the line of sight perpendicular to the stem of the thermometer.

(*To be continued in the May Issue*)

MECHANICAL ENGINEERING

A Monthly Journal Containing a Review of Progress and Attainments in Mechanical Engineering and Related Fields, The Engineering Index (of current engineering literature), together with a Summary of the Activities, Papers and Proceedings of

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Keeping the Atmosphere Clean

WHY IS IT that smoke-abatement efforts do not bring more satisfactory results?

The main reason is an incorrect estimate of the kind and size of the job. When an industrial community realizes that keeping the air clean is a project of similar magnitude to keeping streets clean, providing clean water, removing city waste, or guarding the moral atmosphere, then there may be a real hope of success. We usually think of the project in too small terms. It is thought of as is the dog catcher or the boiler inspector—a matter of a man or two, a job or two, a small appropriation of variable and uncertain amount, to be abolished in a fit of economy and reëstablished under pressure of a vigorous minority.

Even so, it is surprising how much is obtained for the effort; but the community is rarely satisfied, for the job is bigger than it was conceived to be.

Continuous, never-ceasing effort is required to clean up a smoky city. A few months of relaxation and the situation slips back some years of effort.

It is useless to look for a spectacular cure. Success comes only after long continued highly skilful effort. When a new plant goes in and it proves to be a smoker, it is difficult to remedy the condition. The community will probably have to stand smoke for a long time while the owner spends money temporizing with weak expedients, finally arriving at the conclusion that "it cannot be done." The remedy is to provide such engineering oversight of new installations as to insure a non-smoking plant to begin with. This can be done. It may mean changes in building plans, a larger investment, a greater responsibility of management, a more intelligent operation, but these things are the price of clean air. The higher grade of installation usually pays well by reducing running expenses. It is of little use to complain of smoky stacks and allow new ones to be added daily. It is not often that smokelessness is one of the main objectives in an installation. Capacity, convenience, efficiency, and low cost come first, with a weak but laudable hope that smokelessness can be had also at no increase in cost. This order must be reversed in the public mind if we are to have clean air. Smokelessness must be a first requirement. These simple illustrations indicate that successful smoke abatement is a problem requiring high technical ability, the administration of a difficult human problem, a change in attitude of a community, a willingness to wait for results, and a readiness to pay for continuous, long-time effort free from political control. So far we have not found this combination, so that results are partial.

There is a great waste of ineffective effort in smoke-abatement agitation that gets nowhere, because of a lack of vision as to the kind of job it is and an unwillingness to pay the price.

Engineers believe that it can be done, and at a price not out of proportion to its worth.

O. P. Hood.[1]

Engineering Education

NO APOLOGY need be made for presuming to write upon so time-worn a subject as education. Probably thousands of books and hundreds of thousands of articles have been written upon this subject without solving the problem of education. Perhaps the future will record as many or more attempts at a satisfactory solution, and yet there seems no hope beyond temporary success. This is as it should be, for it would be indeed a calamity should the problem be considered solved. The method of disseminating knowledge used by Aristotle would not have been effective a thousand years later, nor are the methods of that more recent date applicable today. Therefore we must expect frequent agitation of a question which is being constantly revived by the disturbing advance of science and illuminating revelations of research. Indeed, every technical society and every scientific society has an educational committee or division. Most social organizations manifest an interest in education, or acknowledge an obligation to disseminate knowledge.

Perhaps there may be certain fundamentals upon which modern engineering education may be considered dependent, and if these can be recognized and so designated the explorations and dissertations of future investigators in educational fields may be at least without alarm.

It is conceivable that a great engineer may come to this country and perform many expert services without being able to speak or write either good or bad English. But even in such a case the aid of a trained assistant would be essential. Certainly no native son not already trained would ever reach fame without a mastery of his own language. The young man advances not only by the information he acquires but by the information he imparts. His success in either phase will be determined by his accuracy. Accuracy can be acquired only by careful discrimination, which in turn is possible only provided one has a discriminating knowledge of English. The reading of editorials, selected biographies, and supervised writing for publications might well be substituted for two of the three R's of our forefathers.

The foregoing is merely the foundation for the superstructure, but is essential for any good superstructure. So evident is the necessity for training in mathematics, physics, mechanics, and design that no claims for those subjects in an educational scheme are needed. Overspecialization is unwise and should not be encouraged except in a post-training scheme. An important factor, too, is the flexibility of a plan based on fundamental and cultural foundations. The student becomes more capable of making a choice of vocation. The turnover would be reduced to a minimum. Environment and opportunity as proved by experience time and again will play so important a part in the engineer's development that their influence cannot be ignored. Modern business methods may offer a young engineer but a brief, unfavorable opportunity to present his cause. The opinion formed of him may be based on a few spoken words and on his personal bearing. If this opinion is favorable, he will have a chance to sell his wares. If he inspires confidence, his opportunities and his influence will grow. As technical information is almost useless without ability to express oneself clearly and forcefully, a thorough training in the fundamentals of English, including presentation, seems essential.

As engineering is business, an argument for the necessity of acquiring the fundamentals of business training is almost as sound as the argument for training in English. At some stage in the development of an enterprise business dealings are essential. To

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relinquish this part of the engineer's service is unjust to the individual and unfair to the engineering profession. Economics, business law, accounting, or banking would supply the need.

The most frequent criticism, perhaps well deserved, of the engineer refers to his personality. The deficiency may not be so designated, but in effect the fault lies in the intangible personality. No amount of technical training will develop personality. Certain features of technical training may favor its development, but only contact with culture or study of cultural subjects may be relied upon. No man can stand forth among his fellows with the assurance of superiority which he must feel in his work if he is to be successful, while the realization of his inferiority in general confronts him. History, pure science, literature, political science, public speaking, art, and music suggest themselves as helpful servants in the building of a positive personality.

The success after graduation of those students who have been active in student affairs causes us to feel that there is some merit in augmenting the classroom training with athletic, forensic, or administrative activities, and indicates that these might well be fostered by the educational system rather than left to chance.

I have a friend who is a fuel dealer, a bank director, and a philosopher. He said to me that the layman is warned by the professional educator to keep his hands off educational policy because he is unqualified to criticize it. He further remarked that he could not play a beautiful sonata, but that he knew when one was being played; that he is not an educator, but that he knows from results that the educators are bungling their work. Here is a theme upon which both educators and laymen may collaborate.

E. O. EASTWOOD.[2]

Standardization by Law

ANENT the current legislation in Congress on the extension of the existence of the National Screw Thread Commission, the New York *Sun* recently recounted the complicated steps necessary in the enactment of laws and asked for a general statute to simplify the establishment of standardizing groups without the necessity of following the devious paths of Congressional enactment.

The National Screw Thread Commission has carried on successfully, and the results it has effected will be useful to commerce and industry. Originated during the war by the need for interchangeability of screw-thread products between many factories, the Commission took up its task and issued its report in 1925.

In its editorial, the *Sun* intimates that similar processes for other standardization projects should be made easy of adoption. There is serious doubt that this would be successful, as a glance at the situation in modern industry will reveal.

In the first place, outside of the basic standards in this country, such as the yard, the pound, and the screw-thread system, standardization by legislation or Government commission is not more practical in the common usages of industry than in the habits of man unless supported by a large body of public opinion. The most important phase of the standardization process is the adoption and use of accepted standards by commerce and industry. Standardization demands a coöperative effort throughout four stages: first, in individual firms; second, by societies and trade associations; third, on a national scale; and fourth, on an international scale. To be really effective a standardization movement should permeate all of the industries of a nation, as most projects extend into the many branches of the same industry. There are in this country hundreds of technical trade associations engaged in standardization activities of some form or other, in addition to the supply branches of the Federal Government and of state governments. It will be obvious that if Government commissions were set up to cover these standardization activities, the size of the legislative program, even though a simple form were developed, would prohibit prompt action.

To fill the need for a clearing house between the many standardizing groups in the country the American Engineering Standards Committee was organized in 1918, and in this body we have a comprehensive, completely coöperative organization for securing the support of industry and the promulgation and adoption of standards of dimension and specification. The method of work under which the A.E.S.C. carries on its activites provides first that all industries interested or affected by the suggested standard be brought together to discuss the project to be taken up and agree that standardization is necessary. The rules of procedure of the A.E.S.C. stipulate the character of the personnel of the committee, representation being assured to all groups who would be affected by the adopted standard. This procedure, which draws into council the active industries and individuals and encourages them to participate in formulating the standard, insures a large body of interested people who, when the standard is finally adopted, are already informed of its purpose and scope and are in a position to employ it actively in their industry. In this way industry is provided with a means for self-assertion which does not require the paternal hand of government, and which in the long run will be more effective than any program of legislation for the enactment of industrial or commercial standards.

The work of the A.E.S.C. is comparatively new. Its influence is growing rapidly, and as standards are adopted under its procedure its effect will be more easily measured. It is sufficient to say, however, that even in the early stages it offers promise of great value to American industry.

Purchased vs. Generated Power

AN ALL-DAY conference on industrial-power problems comprising well-attended morning, afternoon, and evening sessions at which twelve papers convering a wide range of topics were read, was held by the Engineers' Club of Philadelphia on February 16. While it was recognized that each plant presents its own problems and that it is not possible to generalize on the subject, there was nevertheless substantial agreement among those in attendance that isolated plants are justified in factories where considerable quantities of process steam are required.

In a paper entitled Factors Governing Purchase or Generation of Power, W. A. Shoudy said that satisfactory service could generally be obtained today from the public utility except in some of the remote districts, but if it could not, the private plant became a necessity, regardless of the cost of generating power by it.

Substantially all factories had some need of steam for heating or processes. The latent heat was a large proportion of the heat absorbed in the boiler. It could not be used for power, but could be used for heating. In most cases the factory plant was justified only when this latent heat in the exhaust steam was justified. The power then became a by-product and was obtained at low cost. Some industries, such as sugar refineries and certain chemical works and paper mills, used more heat than power, and could therefore obtain all their power as a by-product.

A factory was justified in generating its own power (1) when the power requirements were large and when sufficient condensing water could be obtained; (2) when the entire power could be generated as a by-product power; and (3) when, through coöperation of the factory and the public utility, the entire steam or heat demands of the factory were used for the generation of by-product power and the difference either purchased from or sold to the local utility.

Rates of 16,000 to 20,000 B.t.u. per kw-hr. were about the average for the better central stations. The industrial plant could not hope to meet these figures except through by-product power. If all the process steam were used by plants for power generation, the excess power could be generated for about 6000 B.t.u. per kw-hr., and at a lower cost than it could be generated in a central station.

L. B. McMillan, discussing heat insulation, called attention to the enormous heat waste due to uninsulated kettles and other process containers, and R. H. Heilman, speaking on the same topic, gave instances where pipe coverings had paid for themselves in a short time due to heat saving.

Thomas V. Balch gave particulars regarding the plant of the Equitable Building, New York, which had been successful in competing with utility service; and Francis Hodgkinson discussed the various points to be considered in the use of high-pressure prime movers in industrial plants.

Other papers on the program were: Power-Transmission Economies, by Wm. Staniar; Lubrication and Bearings, by J. D. Gill;

[2] Professor of Mechanical Engineering, University of Washington, Seattle, Wash. Manager, A.S.M.E.

Economy Due to Power-Factor Correction, by E. N. Dittenhofer; Plant Illumination, by Ward Harrison; The Use of Exhaust Steam for Process Work in Textile Plants, by S. M. Green; and Operating with Purchased Power in Competition with Private Power, by Reginald P. Bolton.

Prominent Foreign Engineers and Scientists to Attend U. S. Meeting of I.E.C.

THE meeting of the International Electrotechnical Commission will be held in New York from April 13 through 22 at the Engineering Societies Building. This Commission, which is an international standardizing body in the electrical industry, was organized in 1906 following suggestions made at the Electrical Congress held in St. Louis in 1904. Despite its many years of activity it has never held a meeting in this country, the reason for this being the intervention of the war. The meeting in New York, the first in the United States, will also be the first one which has been held with full representation of all the countries which were active in the Commission prior to the war.

Tentative plans call for the arrival of the European delegates on S. S. *Andania*, due in New York on April 11. The hotel headquarters will be the Hotel Astor. The greater part of the activities of the Commission will center about the meetings of the various advisory committees organized to formulate the work in particular fields and to report their results to the Plenary Meeting of the Commission. The preliminary schedule of the meetings is shown in the accompanying table.

PRELIMINARY PROGRAM OF PLENARY MEETING AND ADVISORY COMMITTEES OF I. E. C., NEW YORK, APRIL 13–22

	Tuesday, 13th	Wednesday, 14th	Thursday, 15th	Friday, 16th	Monday, 19th	Tuesday, 20th	Wednesday 21st	Thursday, 22d
Morning 9.30 to 12.30	Opening Meeting	Prime Movers (Hydraulic Turbines)	Prime Movers (Hydraulic Turbines)	Prime Movers (Hydraulic Turbines)	Rating (Electrical Machinery)	Prime Movers (Steam Turbines)	Committee of Action	Prime Movers (Steam Turbines)
		Rating (Electrical Machinery)	Rating (Electrical Machinery)	Transformer Oils	Transformer Oils	Traction Motors		Terminal Markings
Afternoon 2.30 to 6.30	Experts' Papers on Rating	Prime Movers (Hydraulic Turbines)	Prime Movers (Hydraulic Turbines)	Prime Movers (Hydraulic Turbines)	Prime Movers (Steam Turbines)	Prime Movers (Steam Turbines)	PLENARY MEETING	Prime Movers (Steam Turbines)
		Rating (Electrical Machinery)	Rating (Electrical Machinery)	Transformer Oils	Transformer Oils			Terminal Markings
Evening	General meeting arranged by American Committee	Rules and Regulations	Symbols	Vocabulary	High-Pressure Tests	Lamp Holders and Caps		
			Standard Pressures	High Pressure Tests				

The general meeting in the Engineering Auditorium on the evening of April 13 will be of particular importance. It is proposed that this meeting shall be conducted under the auspices of the engineering and technical societies which support the work of the U. S. National Committee, and that the membership of these societies shall be invited to attend this meeting. The meeting will be addressed by notable engineers from foreign lands and the work and purpose of the International Electrotechnical Commission will be set forth by them.

The American Society of Mechanical Engineers is represented on the Commission by Past-Presidents Fred R. Low and William F. Durand.

There will be a number of entertainment features offered to the visiting delegates, and at the close of the New York meeting a tour will be offered which will include Philadelphia, Washington, Pittsburgh, Chicago, Detroit, Niagara Falls, Ottawa, Montreal, Boston, Schenectady, and New York. The Canadian National Committee, who are coöperating, will welcome the delegates at Niagara Falls and will conduct them to Montreal, where it is expected that a public meeting will be held in their honor.

The delegates will be received in various cities by local committees who will attend to making their stay at these places both profitable and enjoyable.

The preliminary list of delegates indicates that there will be 105 from Europe, including Norway, Russia, Poland, Spain, France, Belgium, Germany, Great Britain, and Switzerland. Among those present will be

Belgium. Frans Dupont and M. E. Uytborok.
France. J. J. Frick and M. E. Roth.
Germany. P. Strecker, President, German Electrotechnical Committee; P. Shirp, Dr. Rudenberg, Dr. Fleischmann, M. Kloss, and Richard Stern.
Great Britain. Sir Richard Glazebrook, Chairman, British National Committee; Sir Archibald Denny, Chairman, British Engineering Standards Association; L. B. Atkinson, W. W. Lackie, L. St. L. Penched, Col. F. T. Purves, C. P. Sparks, Sir George Sutton, W. B. Woodhouse, S. T. Allen, E. G. Batt, S. B. Donkin, A. R. Everest, A. C. Cramb, P. V. Hunter, J. P. Gregory, W. Lee, Lieut-Col. F. A. Cortez Leigh, R. B. Mitchell, W. Pearson, J. S. Peck, C. Rodgers, T. Roles, F. Wallis, and P. Good.
Holland. C. Feldmann, President, Dutch Electrotechnical Committee; Mr. Tromp, Mr. Rosskopf, and Bellaar Spruyt.
Italy. G. Semenza, President, International Electrotechnical Commission; E. Morelli, Mr. Ucelli, and Ernesto Vannotti.
Norway. H. A. Mork.
Russia. Prof. Chatelain.
Switzerland. E. Huber-Stockar, President, Swiss Electrotechnical Committee; A. Huber-Ruf, Charles Burlet, Antoine Schran, H. Zoelly, and Paul Thut.
Poland. C. Drewnowski and Z. Okoniesaki.
Spain. A. Artigas.
United States. W. F. Durand, F. R. Low, C. O. Mailloux, A. E. Kennelly, C. E. Skinner, F. D. Newbury, E. A. Snyder, A. H. Moore, J. Franklin Meyer, C. A. Bates, N. W. Storer, and D. W. Roper.

The first president of the I.E.C. was Lord Kelvin, and Prof. Elihu Thomson was president in 1911 at the time of the meeting in Turin. Dr. C. O. Mailloux is junior past-president and the honorary president of the Commission. The president of the U. S. National Committee is Dr. C. H. Sharp, and the secretary is F. V. Magalhaes. The chairman of the Reception Committee for the foreign visit is John W. Lieb.

Arrangements for the entertainment in New York are in the hands of F. W. Smith, and arrangements for the tour are being perfected by C. E. Skinner.

Mechanization of Coal Mines

THE economic, mining, and mechanical problems incidental to the use of coal-mining and loading machinery in bituminous mines were discussed on March 11 at a meeting of the Metropolitan Section of the A.S.M.E., the program for which was arranged by the A.S.M.E. Materials Handling Division with the coöperation of the National Coal Association.

Under the chairmanship of Eugene McAuliffe,[3] three papers were presented and discussed until nearly midnight by an interested group of engineers and coal operators from fourteen states. In his opening remarks Mr. McAuliffe welcomed the mechanical engineer into the diccussion of the problems relating to mechanization of mines, but emphasized the fact that more than mechanical matters were involved. He pointed out that present mining methods, mining laws and regulations, the attitude of mine operating heads, and the functions of labor would all be affected by the greater use of mechanical equipment in coal-mine operation. Any system of mechanical loading would mean restricted working area,

[3] President Union Pacific Coal Co., and Washington Union Coal Co., Omaha, Neb.

decreased pumping, ventilation, and haulage demand, and would make mine inspection a real possibility and reduce mine accidents.

The first paper of the evening was by Nixon W. Elmer,[4] who dealt with the subject as a materials-handling engineer. Mr. Elmer emphasized the point that in installing mechanical devices in the coal mine each mine must be considered as an entirely separate problem. There was no one best way to handle all types of materials mechanically. He stated that the order of magnitude of possible savings through mechanizing the operations from the face to the haulage entry would appear to be not less than fifty per cent of direct labor, and that there were many means and devices available for achieving this saving. In conclusion, he pointed out that the entire coal-using public was interested in mechaniization of mines, as it would lead the way to a greater stabilization of the industry.

Edwin H. Johnson[5] presented an engineer's viewpoint of mechanical loading as the second paper. He outlined the increased responsibility which management men assumed in purchasing and operating mine-working machinery. He also stated that mechanical loading meant concentration of mine workings, delivery of tonnage from one-quarter to one-half the present developed area, rapid development and recovery of new properties, resulting in quicker, therefore greater, returns from the original investment; saving in timber through more rapid evacuation from a territory; saving in steel rails, mine ties, trolley wire, and bonds for the same reason; possibility for better supervision; and greater safety for men and machinery. These were the intangible advantages which were not always reflected in the direct cost. The big advantage—cost reduction—was sufficiently large to be almost certain that the engineering judgment was not at fault.

The final paper, by Col. Edward O'Toole,[6] contained a description of several types of machines which he had built and operated in the mines of the U. S. Coal & Coke Company at Gary, W. Va. Colonel O'Toole presented figures of cost reduction and increased production per man that were obtained by the use of his machines.

The three papers will appear in the May issue of MECHANICAL ENGINEERING, with an abstract of the interesting and valuable discussion presented at the meeting.

Science in a New Role

THE mighty science of modern warfare that has been developed in this generation is indebted for its effectiveness to the advances in industry and other sciences. Military men and engineers delved into every manner of peaceful and commercial pursuit in perfecting their craft; and they were eminently successful if we may judge from the cries of a united world for peace. Our desolated homes, our economic burdens, our human losses are reflected in the prayers and longing for the outlawing of war.

With this end in view a host of agencies such as the World Court, disarmament conferences, arbitral commissions, and similar activities are assisting in narrowing the limits of possible dissension between nations. There is increasing evidence of the desire and intent of all countries to get the practical processes of peaceful decision in operation. And now the generation that witnessed the greatest war in history is fostering a move in which science may play an equally important role. The plans for the Walter Hines Page School of International Relations provide for scientific research into a field that has always been dominated by factions and continually surged by the varying and uncertain currents of public opinion.

The Page School is the outcome of a series of meetings held about two years ago at which a number of prominent business men, publishers, and educators discussed the paucity of accurate or dependable information on world affairs, and the growing need for some organization to investigate this field with the sole purpose of ascertaining and making available the true facts. The Page School proposals that resulted from these meetings provide for the early institution at Johns Hopkins University of a unit without precedent in the annals of education and research. Manned by scholars and professors who have already attained eminence in their special fields, its object will be to discover, as far as possible, new facts and to assemble and analyze existing knowledge in such a way as to reveal more clearly the precise nature of the causes that lead to wars. It will endeavor to remove the subject from the realm of political speculation and nationalistic bias, and reduce it to a basis of scientific fact.

Briefly, the Page School will endeavor (1) to ascertain the facts, as far as they can be found; (2) to develop a science of international relations, and (3) to produce a continually growing body of men trained in that science and available for service in the fields of education, government, and business.

Owen D. Young, member of the committee of experts that formulated the Dawes Plan, is chairman of the trustees for the endowment Fund. Among those associated with him are John J. Carty, John H. Finley, Adolph Ochs, Julius Barnes, Edward Bok, George L. Radcliffe, French Strother, Van Lear Black, Charles Lathrop Pack, John Agar, John W. Davis, Robert Brookings, Albert Shaw, and George Foster Peabody, and chairmen and committees in upward of fifty cities are making possible the initial endowment of one million dollars through a large number of widespread contributions.

Mr. Young's contributions to world peace have placed him in a position where his views on such subjects are given serious consideration. The Page School, as he discusses it, seems an enterprise of practical idealism.

> This school of international relations [he said recently in *The Independent*] will apply the tried and tested methods of research to world problems. Its purpose is to bring out and correlate the facts underlying the international tangles which lie at the root of war, building gradually a body of organized knowledge in that field to which men of good intent everywhere can refer. That sort of knowledge is as important in the international field as science is in industry. The chief thing we did in Europe, as disinterested experts, was to develop facts which politicians could not disregard.
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> I have no quarrel with politicians; in general, they do the best they can. But to hold power they must defer to public opinion, which is too often uninformed and passionate. No French stateman, in Poincaré's place, could have said: "Germany can't pay at present the schedules established by the Treaty of Versailles. Let us revise the estimates in view of the facts." For him to do so would have been to confess defeat and lose power.
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> The great nations of the world, through their diplomatic services, do collect facts of tremendous importance, but it is in the nature of things that there can be no clearing house for such collections. The primary purpose of diplomatic intelligence is to promote national interest. Consequently, there is need for disinterested study by men fully as acute as the diplomats, but who stand quite outside their interest and whose futures do not depend upon the success or failure of any national aim or policy.
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> No man knows, and it is unimportant that any should know, what the political organization of the planet will be a hundred years hence. The present set-up of world politics is only a few centuries old, and may pass more quickly than it came. But whatever happens to boundaries and governments, water will still run down hill and electric currents and sound waves will be chasing one another through the ether. Assuredly there will be better machines and more of them, and improved communications. Already the telegraph, telephone, and radio have brought nations ear to ear—too close together to make isolation a practical national policy. Only the other day Moscow listened to Schenectady. When unadjusted gears come into conflict, one set gets stripped; when man-made laws conflict with those of nature and science, there is not the slightest doubt which set will strip the other. In this sense the Page School is a definite attempt to give statemanship the material with which it can keep on a par with economic advance.
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> Whatever happens in the future, facts will still be facts and men, men. This generation cannot reasonably hope that its posterity will be supermen; but our successors will be able to do their work far better if we do our level best to provide them with facts now unknown, but merely awaiting discovery. That is a big job, yet surely not too big for a generation which has seen what we have seen, and which is marching from one triumph to another in so many lines of thought and work.

Meeting of Committee on Organization of Public Works

IN FOLLOWING out its plan to develop the most practicable scheme for the organization of the public-works functions of the Government, the American Engineering Council called its committee to study this subject together on March 13 and 14 at the headquarters of The American Society of Mechanical Engineers in New York City.

The purpose of this committee will be to analyze the public-works and public-domain functions of the United States Govern-

[4] Mem. A.S.M.E. Consulting Materials-Handling Engineer, Quincy, Mass.

[5] Coloder Co., Columbus, Ohio.

[6] Genl. Supt., U. S. Coal & Coke Co., Gary, W. Va.

ment, to determine the practicability and desirability of a complete or partial merger of such functions in one department, and to work out the best plan of internal organization for the department in which such functions should be combined.

The leading engineering bodies of the country concerned with organization problems had been called upon by the American Engineering Council to nominate those engineers who were the outstanding recognized authorities on problems of organization, and it is believed that in this way those best equipped to render such conspicuous public service to the Federal Government have been brought together.

All of the engineering functions, as well as those functions which deal primarily with the public domain, will be reviewed from the organization standpoint to determine how they may be modeled into the new organization. The committee is determined to go into detail so that all phases of the problem may be properly understood by its members before the major work of setting up the new department is started. Personal conferences with the heads of bureaus and offices involved in the transfer are planned by the members of the committee, and the views of all of those interested in the problem will be sought by the committee.

The committee has received no instructions from the American Engineering Council and is therefore free to develop that organization layout which will be best suited to the most efficient and effective organization of the new department. While the American Engineering Council has a tentative measure before Congress at the present time, the committee is not bound to abide strictly by it. Any recommendations submitted by the committee would probably, it is understood, be inserted in the bill.

At the first meeting of the committee, E. O. Griffenhagen, senior partner of the firm of Griffenhagen & Associates, Ltd., management engineers, of Chicago, was made its chairman. Mr. Griffenhagen reorganized the Canadian government departments in 1919, was in charge of the congressional commission on reclassification in 1920, and is a prominent member of many engineering societies such as the Society of Industrial Engineers, American Society of Civil Engineers, Western Society of Engineers, Taylor Society, American Association of Engineers, and others. He was selected by the Society of Industrial Engineers for this important public service.

Because of the great amount of interest manifested by Secretary of the Interior Work, and also due to the fact that most of the bureaus concerned with public-works functions are now located in the Department of the Interior, the Secretary was asked to appoint a representative on this committee. The American Engineering Council was especially fortunate in that Dr. Elwood Mead, Director of Reclamation, was named by the Secretary of the Interior. Dr. Mead has been eminently connected with both the Department of Agriculture and the Reclamation Service, where he has given much attention to details of better organization.

Sanford E. Thompson, consulting management engineer, of Boston, who has done a great deal of important work in the development of organizations of commercial and industrial enterprises, was nominated by the Taylor Society.

Col. John Price Jackson, assistant to vice-president of the New York Edison Company, past dean of the School of Engineering at Pennsylvania State College, and commissioner of the Department of Labor and Industry for the State of Pennsylvania, who has devoted much time to organization problems, was nominated for membership on the committee by The American Society of Mechanical Engineers.

Wallace Clark, consulting industrial engineer, of New York City, whose abilities have been extensively utilized by the War Department in the development of improved systems and who was appointed by Secretary Hoover to assist in the reorganization of the Patent Office, was nominated for membership on the committee by the Taylor Society.

J. L. Jacobs, director of the company bearing his name, and who has directed much utility and state work, notably for the state of Illinois, was nominated for membership on the committee by the Society of Industrial Engineers.

W. F. Willoughby, director of the Institute for Government Research, of Washington, D. C., who has written many works on the organization of the various branches of the National Government, and is one of the outstanding authorities on the national budget system, because of his intimate knowledge of all of the services involved in the proposed organization of public works, was invited by the American Engineering Council to serve on this committee.

A. C. Oliphant, assistant secretary of the American Engineering Council, who has been associated with the work of reorganization of the engineering branches of the Government since early efforts in this direction, was selected by the committee to serve as secretary.

Meetings will be held by the whole committee and sub-committees as required, and it is contemplated to have the complete report available for the use of Congress or committees thereof by early fall.

Providence and San Francisco Meetings of the A.S.M.E.

MEMBERS of the A.S.M.E. will have two splendid opportunities to participate in meetings of the Society during the coming spring and summer.

The Providence Section, with the coöperation and assistance of the other New England Sections, has planned an interesting and important meeting to last from May 3 through 6 at Providence. They extend a hearty welcome to all members of the Society to participate in the program of technical sessions, excursions, and entertainment which will take up the four days of the meeting, culminating in an all-day trip by water to Newport to visit the torpedo station.

The technical program will include an important session on apprenticeship training, to be held on Monday afternoon, May 3. Two sessions on machine-shop practice will be held, one devoted to small interchangeable parts and the other to the cold working of metals. These sessions will be held on Tuesday and Wednesday mornings, respectively. Industrial power problems will be discussed Tuesday morning and a group of central-station papers will be presented on Wednesday morning. Papers on woodworking topics will be taken up on Tuesday morning and others on textile subjects on Wednesday. All the sessions will be held on mornings and the afternoons will be devoted to excursions and shop visits.

The San Francisco meeting offers the opportunity for an interesting sightseeing trip lasting thirty days, starting from New York on June 14 and reaching San Francisco in time for the meeting, and arriving back in New York on July 13. Already over three hundred and fifty have signified their intention of making the trip, and indications point to two special trains for the tour.

The Local Sections of the A.S.M.E. on the route of the tour are making elaborate arrangements to welcome the special trains and to give the travelers opportunity to enjoy the various attractions of the cities visited. These stops enroute serve to break the number of consecutive nights on the sleepers, and thus add greatly to the comfort of the members of the party. The care with which plans have been developed, the splendid coöperation shown by the various Local Sections and the railroads, and the interest shown by the members indicate that this will be the most successful excursion ever conducted under the auspices of the Society. Those who are going on the tour will be expected to send their remittance of half the fare to the Secretary on April 15, the remainder is payable on May 15. Checks should be made payable to the Pennsylvania Railroad.

The San Francisco Section has also outlined an intensely interesting program commencing June 28 and lasting through July 1. This program will enable the visitors to become familiar with the scenic beauties and the industrial facilities of the San Francisco district, and will also afford members on the Pacific Coast an opportunity to discuss the engineering problems peculiar to that region. Five sessions have been arranged, one dealing with industrial training and education, one with the problems of the petroleum industry, a third with the combustion of fuel oil and the development of the caterpillar tractor, a fourth with hydroelectric problems, and a fifth with oil and gas power. The papers cover a wide range of subjects in these fields, and in general promise, through their contents and the discussion which they will elicit, to add a great deal of interesting and valuable material to the literature of mechanical engineering.

Complete details of the programs of events of each of these meetings will appear in current issues of the *A.S.M.E. News*.

Annual Meeting of the A.I.M.E.

A Summary of the Papers Presented of Special Interest to Mechanical Engineers

AT THE annual meeting of the American Institute of Mining and Metallurgical Engineers held in New York, February 15 to 18, a number of papers were presented on subjects of interest to mechanical engineers as well as to their colleagues in the profession of mining and metallurgy—which is only natural as mechanical appliances are of course widely used in mining and metallurgy, while certain subjects in the special field of the Institute, such as, for example, coal mining, are of great importance to mechanical engineers.

Pumps and Fans

Several papers dealt with the subject of pumps and fans. L. C. Uren, S. B. Sargent, and V. J. Collins, all of the University of California, in a paper entitled Influence of Submergence on the Efficiency of the Oil-Well Plunger Pump, pointed out that among the several variables which determine the efficiency of the type of plunger pump commonly used in oil-well service, the submergence of the pump below the fluid surface in the well plays an important part. When insufficiently submerged, the pump will deliver less than half of its theoretical plunger displacement. In many instances it seems probable that wells yield only half of what they are capable of producing, because the operator fails to maintain a suitable submergence on the pump. This paper describes the conditions, within and surrounding the pump while in operation in the well, which influence the effect of submergence on pumping efficiency; it presents the results of an experimental study designed to disclose the quantitative effect of submergence on pump efficiency; and offers conclusions which indicate the approximate submergence desirable and emphasize the necessity for a knowledge of operating fluid levels within pumping wells.

The rating of a mine ventilation fan or the characteristic curves illustrating the duty it may be expected to perform under various mine conditions are, in general, determined by the fan manufacturers, states A. S. Richardson (Theoretical Rating Compared with Operating Performance of Centrifugal Mine Ventilating Fans). The information is of importance to the operator, or engineer, of a mine in many ways. For instance, when an increased flow of air is desired and the fan speed is to be increased, it becomes necessary to know what increase in volume may be expected and what the power requirements will be. In other cases, it may be decided to make changes in the mine to reduce the resistance to the flow of air, or to make changes in the general system of ventilation. Under any changed mine conditions there will be a difference in the duty performed by the fan. When mechanical ventilation is adopted, the factors governing the selection of equipment for the new system include not only the requirements of existing conditions, but also those that may be expected with the development of the property. Efficiency of service is required over a variable range of operating conditions.

Characteristic curves giving the duty performed by their fans under variable resistance conditions are published by most fan manufacturers. Textbooks and trade catalogs contain general statements as to the effect of variation in speed of the centrifugal-type fan under fixed mine conditions. To the author both sources of information appear to be unreliable, at least under certain conditions. He points out how shop tests may give information differing from mine performance and explains why this is so. He also expresses a belief that a comprehensive code for testing mine fans should be formulated.

Essentially, the same subject is discussed by Louis W. Huber in a paper entitled, Operating Characteristics of Centrifugal Fans and Use of Fan-Performance Curve. He claims that while it is true that mines are much better ventilated now than they were twenty or thirty years ago, we have made very little progress in the study of mine ventilation or in mine-ventilating-fan design. Old ideas on mine fans persist, such, for example, as manometric efficiency, which is still calculated and emphasized, although most of the manufacturers themselves realize that it is meaningless. He suggests a classification of centrifugal fans according to the curvature of their blades, and among other things suggests selling fans on the basis of a guarantee of performance curve.

Coal

A. C. Fieldner and W. A. Selvig (Relation of Ash Composition to the Uses of Coal) do not believe that "ash is ash," and that determining the amount of ash alone is sufficient. For the efficient washing of coal to remove ash-forming constituents and for the most efficient utilization of coal, it is desirable to know the composition and distribution of the ash-forming constituents. Such information has a direct bearing on clinker and slag trouble often experienced in burning coal, etc. They point out also that as a rule coal ash as determined weighs less than the mineral matter from which it is produced. This is due to the loss of volatile constituents during ignition and makes it necessary to use "corrected ash" values. Otherwise data in regard to sulphur present and water of hydration in clayey matter may become quite misleading.

"Air-sand" is the term which has been given to a process of separating refuse material from coal by means of a body of dry sand artificially fluidized and maintained in that condition by a continuous stream of air bubbles flowing through the sand body (The Air-Sand Process of Cleaning Coal, by Thos. Fraser, and H. F. Yancey). By proper regulation of the rate of air flow, this fluid air-sand body may be maintained at such a density that coal will float near the surface and the refuse, which is heavier, will sink through the sand to the bottom of the container. This separation is a float-and-sink operation similar to the separation of wood chips and stones in water; the one floats and the other sinks, irrespective of size of pieces. This was the objective sought in the development of this method of cleaning coal—a dry process which requires no preliminary sizing of the coal.

The extent to which geological carbonization has taken place in the process of coal formation is a fundamental factor in all considerations relating to classification, oxidation, deterioration, spontaneous combustion, and especially in all considerations relating to destructive distillation having as an objective the production of marketable coke and by-products. (S. W. Parr, Relation of Origin and State of Carbonization of Coal to Problems of Low-Temperature Carbonization.) Moreover, it may be readily shown that a striking relationship exists between the geological carbonization processes and those artificially produced by heat. This is illustrated in the original paper by bringing again to view some of the charts more commonly met with 25 years ago. In this figure the line of geological decomposition by decay, pressure, etc., because of its relation to the line of carbonization by destructive distillation, becomes of special significance when we attempt to formulate any system of classification which shall be reasonably scientific and at the same time of practical or industrial value. We are all familiar, for example, with the method of designating the coking quality of a coal by reference to the amount of residual oxygen in the coal substance—or the ratio of such oxygen to the hydrogen present. This suggests the possibility of devising a method of coal classification which shall at once indicate the degree of geological carbonization by destructive distillation. Such a method seems to be met in a fairly satisfactory manner by a system of classification in which the oxygen present makes its presence evident by its negative effect on the calorific value of the pure or unit coal substance.

To bring about carbonization with the formation of coke the essential conditions are by no means simple, and a warning is issued to the effect that the full information is not always revealed by the single factor of unit heat value. Some of these conditions are discussed under special headings—melting point, bituminic material (which is referred to as the crux of the matter), and oxidation effect.

Crushing Phenomena

A paper on this subject was presented some years ago in connection with the work of the Edison Companies in New Jersey on

crushing iron ore (Edison Roll Crushers, by W. H. Mason, Trans. A.S.M.E., vol. 33, 1911, p. 145). A new study of the same subject was undertaken by A. M. Gaudin (An Investigation of Crushing Phenomena) in order to condense information concerning comminution, and covering a great variety of conditions, into one or several rules which would be of use in the development of a systematic theory as well as in many directly practical ways. As a result of this work, the following conclusions appear justified:

1 Rocks may be classified, from the point of view of comminution, into two general classes which are (*a*) structurally homogeneous, and (*b*) structurally heterogeneous. Structurally homogeneous rocks are those in which fracture takes place through grains and grain boundaries alike; heterogeneous rocks are those in which fracture passes in preference through grain boundaries.

When the logarithmic size curve of a crushed product obtained from sized feed is not a straight line, the rock is heterogeneous in character under conditions that yield a straight line in the fine range with quartz as feed. The position of the hump in the curve indicates the size to which the rock breaks in preference. The height of the curve is in a way a measure of the intensity of this preferential action.

2 If a sized product composed of structurally homogeneous rock grains is crushed, a product results in which the relation between the percentage weight of grains of various sizes, and these sizes themselves follows a definite law. This is not true of structurally heterogeneous rocks.

3 Ball milling with structually homogeneous rocks, and under certain conditions, presents exceptions to this rule.

4 In ball milling with structurally homogeneous rocks there exists a critical ratio of size of feed to size of balls, above which the machine operates essentially by surface wear, and below which it operates essentially by breaking across the body of the particle.

5 In ball milling, with structurally homogeneous rocks, and when the size of feed grains exceeds the critical size, the particles worn off are of a substantially definite size when size depends upon the ball size.

6 In the case of a typical heterogeneous rock, such a Manhattan schist, particles are crushed in such a way that there is a greater proportion of grains of the size that is the average grain size of the rock than there would be in that range of size with a structurally homogeneous rock. This has been found to be true with all the crushers tested.

7 Different methods of crushing produce grains of different shapes.

8 The importance of sizing the 200-mesh portion of a crushed product, in crushing-efficiency investigations, has been greatly underestimated. Without accurate information concerning material of that range of size, the usefulness of efficiency computations is doubtful.

Sand and Gravel

In the year just past there were produced in the United States about 170,000,000 tons of sand and gravel (Washing and Sizing Sand and Gravel, by Edmund Shaw). Much of this was pit-run material used for graveling roads and as railroad ballast on lines that did not carry traffic, but more than half of it was marketed as washed and sized, or graded, material.

The methods used for preparing sand and gravel for the market have long been used in ore dressing and, as in ore dressing, depend on differences in the specific gravity of two substances or in the size or weight of particles. But many changes in the design and operation of plants and machines have been necessary. In ore dressing the concentrate is only a small part of the feed; in sand and gravel washing it is much the larger part of the feed. In addition, such close work as is needed when concentrating a metallic ore is not needed when washing gravel; the ability to put through a large tonnage is more important, and sizing, which is only a preliminary process in ore dressing, is an end to be attained.

Rock crushers are found in most sand and gravel plants and they are used to break up the larger pieces from the deposit (known as boulders and cobbles) which are removed by a scalping screen. The crusher discharge is usually sent back to the scalping screen, the perforations in this screen setting the maximum size of the finished product.

Magnesium-Base Alloys

The constitutional diagram and mechanical properties of magnesium-aluminum alloys are reviewed by Prof. Bradley Stoughton and M. Miyake. A review of the constitutional diagram of magnesium-zinc alloys would indicate the existence of a solid solution on the magnesium side. The mechanical properties of magnesium-zinc alloys, including electron, are reviewed, and a table giving the physical and mechanical properties of this latter is given in the original articles. Among other things it has been found that the magnesium-zinc alloys can be hardened by quenching in water from a temperature somewhat below the solidus, followed by reheating to a temperature higher than room temperature.

Endurance Properties of Non-Ferrous Metals

This paper, by D. J. McAdam, Jr., is a continuation of previous publications by the same author and presents stress-cycle graphs for five samples of monel metal and three high-strength aluminum alloys. These graphs are evidently curves with horizontal asymptote. The position of the horizontal asymptote can be determined with sufficient accuracy by extending the experiments to not more than 50,000,000 cycles. For some of the graphs there is a slight downward slope between 50,000,000 and 100,000,000 cycles. The slope is so slight, however, that extrapolation from 50,000,000 to 100,000,000 cycles gives the endurance limit with sufficient accuracy. Monel metal and duralumin are not exceptional among nonferrous metals in endurance properties.

Cold-Worked Metals

Prof. Chas. Y. Clayton discusses The Effect of Annealing upon the Hardness of Cold-Worked Ingot Iron. It was found that cold compressed iron (0.030 carbon), regardless of the amount of cold work, hardens upon being annealed at a temperature within the blue-heat range between 250 and 425 deg. cent. Samples compressed under loads of 20,000, 30,000, 35,000 and 40,000 lb., respectively, soften upon being annealed between 500 and 600 deg. cent. Samples compressed under loads of 10,000 and 15,000 lb. do not soften upon being annealed. The paper gives a table of Rockwell hardness of ferrite after compressing with various loads followed by an anneal.

A Photomicrographic Study of the Process of Recrystallization in Certain Cold-Worked Metals, is the title of a paper by V. N. Krivobok. The author endeavored to determine experimentally how and why recrystallization occurs, the experimental work being carried out primarily on single crystals of an iron-silicon alloy containing 1.76 per cent silicon and a negligible amount of other impurities. The crystals were of quite large size. Among other things, the author found that apparently one of the conditions of recrystallization is the time that is permitted to elapse between the cold working and the heating, so that complete recrystallization is caused by cold work only if immediately followed by heating. If a certain length of time has been permitted to elapse between the heating and cold working, the samples have always contained traces of incomplete recrystallization.

Carbon Steels

Francis B. Foley, Chas. Y. Clayton, and W. E. Remmers of the U. S. Bureau of Mines presented a paper on the Influence of Temperature, Time, and Rate of Cooling on Physical Properties of Carbon Steel, an extension of an investigation started in 1919. The results obtained show the same general phenomena as observed on the work done on 0.34 and 0.52 per cent carbon steels. The present investigation covers steel of 0.75 per cent carbon content.

Although the tendency in this carbon steel is to increase in strength, hardness, and ductility with increase in cooling rate, the increase, particularly with respect to notched impact value, is not so great nor so sustained as was found to be with the steel of C 0.34 per cent. The phenomenon of increase in Charpy impact value with increase in cooling rate, up to certain limits (plain air cooling), agrees with the results obtained with C 0.34 per cent steel. The lowest values for all of the physical properties obtained were those resulting from a very slow rate of cooling from above the critical temperature. This applies to hardness, ductility, and toughness as judged from impact-resistance values.

Book Reviews and Library Notes

THE Library is a cooperative activity of the A.S.C.E., the A.I.M.E., the A.S.M.E. and the A.I.E.E. It is administered by the United Engineering Society as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West 39th St., New York, N. Y. In order to place its resources at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies of translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

Books Received in the Library

AMERIKAS GIESSEREIWESEN. By U. Lohse. V. D. I. Verlag, Berlin, 1926. Paper, 6 × 8 in., 59 pp., illus., 4.50 gm.

A report upon an extensive tour of American foundries undertaken to inform the German founders concerning modern American practice in founding and foundry equipment. The account pays especial attention to recent advances made in technique and apparatus.

BORDELN UND ZIEHEN IN DER BLECHBEARBEITUNGSTECHNIK. By Erich Ruhrmann. V. D. I. Verlag, Berlin, 1926. (Forschungsarbeiten auf dem Gebiete des Ingenieurwesens, Heft 277.) Paper, 8 × 10 in., 35 pp., illus., diagrams, 6 gm.

A study of the forming of hollow articles by flanging and drawing metal sheets. The author describes the steps involved and also the consumption of power, labor, and time in a series of simple equations which may be applied easily, and gives diagrams showing the results of various investigations. A second part describes some research work undertaken with an apparatus especially designed for the purpose, and presents some inferences, drawn from these experiments, concerning tools. The book should assist in improving the output and quality of stamped ware.

CIVIL AVIATION—A Report by the Joint Committee on Civil Aviation of the United States Department of Commerce and the American Engineering Council. McGraw-Hill Book Co., New York, 1926. Cloth, 6 × 9 in., 189 pp., diagrams, maps, tables, $2.50.

This book presents the results of an extensive survey of the situation in civil aviation, both here and abroad. It includes a comprehensive review of the accomplishments throughout the world, discusses the problems that have arisen and makes recommendations for its promotion in this country.

DAS DEUTSCHE PATENTRECHT. By F. Damme and R. Lutter. Third edition. Otto Liebmann, Berlin, 1925. Paper, 6 × 9 in., 692 pp., 28 mk.

A new edition of a standard text on German patent law and practice, prepared by a former and the present director of the Patent Office. The discussion is comprehensive and practical as well as thoroughly up to date.

DIESEL MASCHINEN—ENTGASEN UND VERGASEN—TECHNISCHE MECHANIK. V. D. I. Verlag, Berlin, 1925–26. 3 vols. Paper, 8 × 12 in., respectively, 97, 116 and 71 pages, illus., diagrams, not quoted.

These three publications contain collections of important articles on their various subjects, selected from recent issues of the *Zeitschrift des Vereines deutscher Ingenieure* and reprinted in this form for convenient use. The volume on Diesel engines contains articles on the Diesel locomotive from the viewpoint of locomotive construction, Diesel engines and gearing for large oil locomotives, high-speed Diesel engines for vessels, compressorless Diesel engines, etc.

The volume entitled Entgasen und Vergasen considers various problems of fuel preparation and utilization. Among these are coal dressing, gas distribution, the improvement of coking coal at the mine, dry cooling of coke, the distillation of low-grade fuels, the Lurgi distillation process, the mechanical influence of fuel in gas generators, and new knowledge in firing practice.

Among the papers on technical mechanics are a criticism of thermal engines, heat transfer from oil to water and loss of pressure in cooling apparatus, heat transmission and loss of pressure in pipe coils, parallel flow and turbulence in circular pipes, resistance to flow in pipes, errors in the measurement of the temperature of flowing gases, fine measuring tools for tension in machine parts, and the solution of statically indeterminate systems by means of the Nupubest instrument.

FESTSCHRIFT ANLÄSSLICH DES 100 JÄHRIGEN BESTEHENS DER TECHNISCHEN HOCHSCHULE FRIDERICIANA ZU KARLSRUHE. C. F. Müller. Karlsruhe, 1925. Three-quarter cloth, 7 × 10 in., 542 pp., illus., diagrams, tables.

A handsome volume commemorating the centenary of the oldest technical college in Germany. It contains 38 papers by members of the faculty, dealing with various subjects—mathematical, economic, mechanical, electrical, chemical, and physical. A history of the beginnings of technical education is included. Among the papers of especial interest to engineers are: simplification of arch calculations, methods of colonizing, city planning and building as a province of engineering, the influence of repeated loads on the elasticity and strength of concrete and reinforced concrete, band spring drives, calculation of shearing stress produced by punching, heat transmission to water in a tube, experiments on the straightening of crooked rods, and safety and economy of electric power transmission.

FORECASTING, PLANNING AND BUDGETING IN BUSINESS MANAGEMENT. By Percival White. McGraw-Hill Book Co., New York, 1926. Cloth, 6 × 8 in., 267 pp., graphs, forms, $2.50.

A manual of planning practice intended for business men and students. The author discusses the factors to be considered: the sources, presentation and interpretation of data, planning technique, production, marketing, etc.

FRESH AIR AND VENTILATION. By C.-E. A. Winslow. E. P. Dutton & Co., New York, 1926. Cloth, 5 × 8 in., 182 pp., $2.

Experimentation during the past twenty years, culminating in the investigations of the New York State Commission on ventilation, has radically changed our conception of what constitutes good ventilation and our knowledge of how to obtain it. Much of this, however, is not generally known, as the information is buried in technical periodicals and reports, so there has been need for a clear presentation of the subject to the general reader. The present volume aims to fill this need by giving a broad outline of the modern idea of good ventilation, and showing how it may be obtained under varying conditions.

GALVANIZING. By Heinz Bablik. E. & F. N. Spon, London; Spon & Chamberlain, New York, 1926. Cloth, 6 × 9 in., 168 pp., illus., tables, $5.

As the manager of a large Austrian galvanizing works, the author has carried out various scientific investigations on the subject, which are assembled in this book. His purpose is to explain, in the light of modern scientific conceptions, processes already known in outward form. Opening with a discussion of rust and its prevention, succeeding chapters deal with the structure of galvanized coatings, picklings, fluxes, hot galvanizing, raw materials and waste products, electro-galvanizing, sherardizing, metal spraying, and the testing of products.

GRAPHIC METHODS FOR PRESENTING BUSINESS STATISTICS. By John R. Riggleman. McGraw-Hill Book Co., New York, 1926. Cloth, 6 × 9 in., 231 pp., illus., graphs, $2.50.

An attempt to outline the fundamentals of graphic presentation as applied to business statistics, and to illustrate current practice in this field. The author has endeavored to make the text clear to those without previous experience and to illustrate every essential point. The book is based on teaching and consulting experience.

KILN DRYING OF LUMBER. By Arthur Koehler and Rolf Thelen. McGraw-Hill Book Co., New York, 1926. (Industrial education series.) Cloth, 6 × 9 in., 293 pp., illus., diagrams, tables, $3.

Based on practical experience in teaching the subject by correspondence and intended primarily for home study, this book aims at a simple yet accurate and logical presentation of a working knowledge of the principles that underly the successful seasoning of lumber in kilns.

LES VÉHICULES AUTOMOBILES. By A. Boyer-Guillon. J.-B. Baillière et fils, Paris, 1926. Paper, 6 × 9 in., 378 pp., illus., diagrams, 55 fr.

As head of the testing laboratory of the Conservatoire National des Arts et Métiers, the author of this book has made numerous tests of automobiles. In this work he has acquired a thorough knowledge of the functioning of these vehicles and their organs and has had an opportunity to compare different devices. The results of his experience are given in this engineering study of the automobile, which presents a number of new points of view.

POPULAR RESEARCH NARRATIVES, vol. 2; collected by the Engineering Foundation. Williams & Wilkins Co., Baltimore, Md., 1926. Cloth, 5 × 8 in., 174 pp., portraits, $1. (Gift of the Engineering Foundation.)

The wide general interest that the first volume of Research Narratives excited has led the Engineering Foundation to publish a second volume. Here are fifty brief stories of useful inventions and discoveries, showing how the scientist and engineer proceed in advancing the welfare of mankind. The accounts are written in non-technical language, with unusual brevity, by men of experience in the subjects treated.

STRENGTH OF MATERIALS; a Treatise on the Theory of Stress Calculations for Engineers. By John Case. Longmans, Green & Co., New York; Edward Arnold Co., London, 1925. Cloth, 6 × 9 in., 558 pp., diagrams, tables, $10.

The author has attempted to produce a book which will deal fully enough with elementary principles to meet the requirements of the student who meets the subject for the first time, and which will also cover adequately the needs of the advanced student. The work, in other words, is one in which the student can begin and complete his studies. The book covers the requirements of those reading for an honors degree in English universities, and is also intended to be of service as a reference textbook to the practicing engineer.

TALKS ABOUT RADIO. By Sir Oliver Lodge. George H. Doran Co., New York, 1925. Cloth, 6 × 8 in , 267 pp., $2.50.

Sir Oliver Lodge writes informally and interestingly of various topics connected with radio, addressing his book to the large army of amateurs. Among the subjects touched upon are broadcasting, the work of the pioneers, the discovery of the waves, and the development of radiotelegraphy. The vast range of ether vibrations, the transmission of wireless waves, their peculiarities, and the general theory of ether waves are discussed. The second part is concerned with some details that make for efficiency, and the third part gives advice and simple rules for various calculations that the amateur constructor needs.

THEORY AND PRACTICE OF COMBUSTION. By J. E. Lister and C. Harman Harris. D. Van Nostrand Co., New York, 1925. (Chemical Engineering Library.) Cloth, 5 × 8 in., 150 pp., diagrams, tables, $2.

A brief compendium of information upon the theory of combustion, the properties of the various fuels in general use, the indicating and recording instruments required for furnace control, and the practical operation of furnaces. The book is intended to present the factors that are important in the efficient working of a furnace in a convenient form for reference by engineers of steam and furnace plants.

TOOL ENGINEERING; PUNCHES, DIES AND GAGES. By Albert A. Dowd and Frank W. Curtis. McGraw-Hill Book Co., New York, 1925. Cloth, 6 × 9 in., 341 pp., illus., forms, $3.50.

In this, the third and concluding volume of this series on tool engineering, the authors discuss dies for forging and for punch presses, the design of gages for interchangeable manufacture, the limit systems, modern drafting-room practice, elementary patternmaking, feeds, speeds, and cutting lubricants. Particular attention has been given to the design of dies. Fundamental principles are dealt with as simply as possible, and their applications to many specific examples of dies and gages in use in leading American factories are shown.

STATISTICAL WORK OF THE NATIONAL GOVERNMENT. By Laurence F. Schmeckebier. Johns Hopkins Press, Baltimore, 1925. (Institute for Government Research. Studies in Administration.) Cloth, 6 × 9 in., 574 pp., tables, $5.

This volume attempts to show clearly and comprehensively what the National Government has done and is doing in collecting and publishing information of a statistical character. It indicates what statistics are available, where they may be found, and how they may be obtained. With its wealth of data and thorough index, it will prove very useful to business men and others in need of statistics.

TURBINES HYDRAULIQUES. By A. Rateau, D. Eydoux and M. Gabriel. J.-B. Baillière et fils, Paris, 1926. Paper, 6 × 9 in., 692 pp., diagrams. Price not noted.

The first volume of a three-volume work which will survey the entire subject of hydraulic turbines on an extended scale. This volume, which is chiefly, the work of D. Eydeux, Professor of Applied Hydraulics at the Ecole Nationale des Ponts et Chaussées, treats of the general subject of hydrodynamics and the theories applicable to turbines. The first section is devoted to general hydrodynamics. The second discusses the direct application of hydrodynamics to turbines. The final section discusses the hydrodynamics of the feed conduits. A bibliography and an index are included. The book is a successful attempt to bring together the useful results of investigators, both in France and elsewhere, and arrange them in a coherent treatise.

USINES HYDROÉLECTRIQUES. By Charles L. Duval and J. L. Routin. J. B. Baillière et fils, Paris, 1925. Paper, 6 × 9 in., 512 pp., illus., diagrams, 60 fr.

A general textbook on hydroelectric power plants. The authors give a description of these plants as a whole, showing the various apparatus used and explaining the reasons that have led to its choice in each case, its dimensions and its use. Both hydraulic and electric features are discussed, but details of the construction of the apparatus are omitted. The book is based on the course at the Ecole Supérieure d'Electricité.

THEORY OF MEASUREMENTS. By Lucius Tuttle and John Satterly. Longmans, Green & Co., London and New York, 1925. Cloth, 6 × 9 in. 333 pp., diagrams, $4.50.

This textbook is intended for use in connection with courses in physics or mathematics. It emphasizes general considerations of measurement, theory of errors, general methods of procedure, quantitative accuracy, adjustment of observations, and similar topics that are usually merely mentioned in a laboratory manual, but that need laboratory work and drill as much as measurements of individual quantities. It is also adapted for use as a reference book. The work represents a course given in the University of Toronto.

TREATISE ON THE LAW OF PUBLIC UTILITIES. By Oscar L. Pond. Third edition. Bobbs-Merrill Co., Indianapolis, 1925. Buckram, 7 × 10 in., 1065 pp., $10.

An endeavor to give a full, impartial exposition of the law of municipal public utilities. The book is based on the decisions of the courts and the various commissions, so that it is authoritative and practical. The new edition contains an extended study of motor-vehicle transportation and a chapter on the subject of appeals.

THE ENGINEERING INDEX

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THE ENGINEERING INDEX presents each month, in conveniently classified form, items descriptive of the articles appearing in the current issues of the world's engineering and scientific press of particular interest to mechanical engineers. At the end of the year the monthly installments are combined along with items dealing with civil, electrical, mining and other branches of engineering, and published in book form, this annual volume having regularly appeared since 1906. In the preparation of the Index by the engineering staff of The American Society of Mechanical Engineers some 1200 technical publications received by the Engineering Societies Library (New York) are regularly reviewed, thus bringing the great resources of that library to the entire engineering profession.

Photoprint copies (white printing on a black background) of any of the articles listed in the Index may be obtained at a price of 25 cents a page. When ordering photoprints identify the article by quoting from the Index item: (1) Title of article; (2) Name of periodical in which it appeared; (3) Volume, number, and date of publication of periodical; (4) Page numbers. A remittance of 25 cents a page should accompany the order. Orders should be sent to the Engineering Societies Library, 29 West 39th Street, New York.

AERODYNAMICS

Magnus Effect. The Magnus Effect and its Technical Application from Elementary Mechanical Viewpoint (Der Magnus-Effekt und seine technische Anwendung in elementarer maschinentechnischer Betrachtung), O. Trautmann. Dinglers Polytechnisches Jl., vol. 12, no. 340, June 1925, pp. 133–135, 2 figs. Discusses Flettner rotor ship and calculation of forces involved; also forces required to replace sail surface of sailing vessels by rotors.

AERONAUTICAL INSTRUMENTS

Altimeters. Behm Acoustic Sounder for Aircraft. Nat. Advisory Committee for Aeronautics—Tech. Memorandums, no. 346, Jan. 1926, 5 pp., 3 figs. on supp. plates. This sounder enables non-barometric determination of altitude by night or in fog which functions on acoustic principle of water sounder, the sound waves passing from airship to ground and return. Translated from German.

AERONAUTICS

Developments. Possible Lines of Aeronautical Development, R. F. Hall. Aviation, vol. 20, no. 7, Feb. 15, 1926, pp. 218–220, 14 figs. Development of compound wings; helicopter possibilities; reducing landing speed; additional wing attachments; vertical flight; construction; monocoque construction; metal-wing structures; airplane glider.

Model Testing. Aeronautical Model Testing, S. S. Rathbun. Brooklyn Engrs. Club—Proc., vol. 24, Oct. 1925, pp. 50–63, 11 figs. Work done by Aeronautic Staff of Bureau of Construction and Repair at Washington Navy Yard during war; comparison of aeronautic, hydraulic and marine problems; discussion of wind tunnels and other equipment for model testing; prediction of performance of full-sized machines from tests on small models, etc.

AIR

Pollution by Smoke. Measuring the Smoke Pollution of City Air, J. S. Owens. Analyst, vol. 51, no. 598, Jan. 1926, pp. 2–18, 5 figs. Divides methods of measuring into those aiming at measuring deposit of impurity from the air and those dealing with impurity while suspended in the air; filtration of suspended matter, washing it out with water, electrical precipitation; measuring deposit; dust counters and other methods.

AIR COMPRESSORS

Electric Motors For. Power Drive Equipment for Air Compressors, G. Fox. Indus. Engr., vol. 84, no. 1, Jan. 1926, pp. 13–18, 8 figs. Type and capacity of motor required, control apparatus necessary and mechanical connection for coupling motor to compressor.

Two-Stage. Air Compressor for a Durham Colliery. Iron & Coal Trades Rev., vol. 112, no. 3018, Jan. 1, 1926, p. 16, 2 figs. Design of two-stage vertical double-acting compressor constructed by Browett, Lindley & Co., Manchester, operating on a steam pressure of 60/80 lbs. per sq. in. superheated to a total temperature of 424 deg. fahr. and exhausting against a back pressure of 2½ lb. above atmosphere.

AIR CONDITIONING

Humidifying System. The Humidity Problem, A. C. Willard. Sheet Metal Worker, vol. 16, no. 24, Jan. 1, 1926, pp. 863–865, 2 figs. Fundamental requirements for successful humidification, cost of evaporating by electricity, gas, etc.

AIR COOLING

Buildings. "Cooling with Coal" Widens Market, R. D. Hall. Coal Age, vol. 29, no. 2, Jan. 14, 1926, pp. 39–42, 2 figs. Discusses cooling of air in theaters, offices, factories, stores, hotels, homes, etc., by refrigeration plants, electric power for which is generated with coal; Chicago Theater's 300-ton plant.

AIRCRAFT

U. S. Naval Factory. United States Naval Factory, S. J. Zeigler, Jr. U. S. Naval Inst.—Proc., vol. 52, no. 275, Jan. 1926, pp. 83–94, 3 figs. Activities of Naval Aircraft factory intended to develop and manufacture experimental aircraft and aircraft accessories, also a limited amount of aircraft production work, and to obtain information on civil production costs, engine-testing laboratory, etc.

AIRCRAFT CONSTRUCTION MATERIALS

Dopes. Dopes and Their Application. Air Service Information Circular, vol. 6, no. 544, Nov. 1, 1925, 11 pp., 18 figs. Discusses composition, tests and storage of dope, a colloidal solution of cellulose acetate, and application with brush or by spraying.

AIRPLANE ENGINES

Bristol Cherub. The New Bristol "Cherub." Flight, vol. 18, no. 2, Jan. 14, 1926, pp. 19–22, 3 figs. Details of Cherub Series III, developing normal power of 33 b.hp. at 2900 r.p.m. and a maximum of 36 b.hp. at 3200 r.p.m. with results of 100-hour tests.

Fiat. A New Fiat Engine. Aviation, vol. 20, no. 7, Feb. 15, 1926, p. 223, 1 fig. Results of tests on A20, 12-cylinder V-type engine with direct-driven propeller.

Japanese. The Mitsubishi 470 Hp. Airplane Engine, S. Ogawa. Soc. Mech. Engrs. (Japan)—Jl., vol. 29, no. 105, Jan. 1926, pp. 1–24, 7 figs. Design of a new engine by Mitsubishi Co., 470 hp., 1600 r.p.m., direct drive, 12 cylinders, 3 lines on four cranks; fuel consumption, 0.22 kg. per hp-hr. (In Japanese.)

Knight-Type. Belgium Adopts New Knight-Type Airplane Engine, W. F. Bradley. Automotive Industries, vol. 54, no. 8, Feb. 25, 1926, pp. 371–374, 5 figs. Sleeve-valve engine built by Minerva passes official test; 12-cylinder model will develop 600 hp.

Lubrication. Practical Notes on Lubricating Commercial Engines with Mineral Oils (Considérations pratiques sur le graissage des moteurs d'avions commerciaux au moyen des huiles minérales), M. H. Jancel. Aéronautique, vol. 7, no. 79, Dec. 1925, pp. 461–463, 2 figs. Results of tests made in 110-hr. flight with Lorraine-Dietrich 12-DA, 375-hp. engine on Paris-Zurich line, to determine advantage of mineral oil and conditions of practical use; concludes that percentage of deposition and of organic matter can be reduced to sufficiently small proportion.

Meteormotor. The Meteormotor Engine. Aviation, vol. 20, no. 9, Mar. 1, 1926, p. 296, 2 figs. Four-cylinder radial air-cooled engine for light airplanes, designed by J. F. Irwin.

Packard. The Evolution of an Aircraft Engine, E. E. Wilson. U. S. Naval Inst.—Proc., vol. 52, no. 275, Jan. 1926, pp. 72–82, 4 figs. Describes evolution of Packard 1A-2500 engine rated at 800 hp. and 2000 r.p.m. with a dry weight of 1113 lbs. or 1.39 lbs. per hp.; highest powered and lightest engine in United States service.

Pratt and Whitney Wasp. The Pratt and Whitney Wasp Engine. Aviation, vol. 20, no. 7, Feb. 15, 1926, pp. 228 and 230, 2 figs. New 9-cylinder radial air-cooled engine of very low weight per horsepower.

Two-Cycle. Two-Stroke-Cycle Engines for Airplanes, J. Jalbert. Nat. Advisory Committee for Aeronautics—Tech. Memo., no. 347, Jan. 1926, 23 pp., 17 figs. Application of two-stroke engines to airplane after their adoption in automobiles; reduced heating; scavenging exhaust gases; intake, fuel consumption, alimentation, distribution, carburetion, idling speed, ignition; Laviator, C. F. A. and other engines. Translated from Aeronautique, July and Aug. 1925.

Wright Simoon. The Wright Simoon Air-Cooled Engine. Aviation, vol. 20, no. 5, Feb. 1, 1926, p. 151, 1 fig. New radial engine with 9 cylinders.

Wright Whirlwind. The Commercial Use of Wright Whirlwind 200-Hp. Air Cooled Engines. Aviation, vol. 20, no. 3, Jan. 18, 1926, pp. 79–80, 1 fig. Commercial possibilities realized; commercial designs; closed-cabin plane; forest-fire fighting plane.

AIRPLANES

Airfoils. The Rolling and Yawing Moments of an Aerofoil in Straight Flight, H. Glauert. Aeronautical Research Committee—Reports & Memoranda, no. 980, July 1925, 5 pp. Concludes that induced yawing moment can be reduced to some extent by use of tapered wings whose tip chord is less than half the central chord, but possibility of obtaining no yawing moment about wind axes depends on some device which introduces a profile yawing moment of the opposite sign to induced yawing moment.

Airship vs. Airplane and Airship: Their Spheres of Economic Usefulness, H. F. Parker. Soc. Automotive Engrs.—Jl., vol. 18, no. 2, Feb. 1926, pp. 175–184, 5 figs. Their dissimilar characteristics: aerodynamic efficiency; comparison of gross lift-thrust ratios; waste of lifting gas; water recovery; hydrogen burning; relation of weight to load; increase of deadweight to load; comparison of useful fields; long-distance voyages. Similar characteristics: initial percentage of useful load; percentage of deadweight to gross load; initial cost; relative operating costs; insurance and safety, etc. On account of its aerodynamic superiority, airship will be used wherever possible for carrying passengers in comfort.

Autogyro Flying Machines. The Development of the Autogyro, de la Cierva. Roy. Aeronautical Soc.—Jl., vol. 30, no. 181, Jan. 1926, pp. 8–19 and (discussion) 19–29, 27 figs. Review of development traced by inventor.

Avia. Czecho-Slovakia Avia Airplanes (Tschechoslowakische Avia-Flugzeuge), Luftfahrt, vol. 29, no. 22, Nov. 20, 1925, pp. 347–349, 5 figs. Details of Avia-B.H. 21, B.H. 21R, B.H. 10, B.H. 11, and B.H. 9, the last one used in flight from Prague to London; equipment and principal data.

Bombers. The C.P.A. 1 Twin-Engine Bomber. Aviation, vol. 20, no. 9, Mar. 1, 1926, p. 298, 1 fig. Non-cantilever monoplane built of wood; equipped with two 450 to 500-hp. Hispano-Suiza engines.

Buhl-Verville. The Buhl-Verville Airster CW-3. Aviation, vol. 20, no. 4, Jan. 25, 1926, pp. 111–112, 3 figs. General-service commercial plane of sturdy construction; folding wings a notable feature; tail unit consists of stabilizer, vertical fin, divided elevator and rudder; equipped with 90-hp. Curtiss OX5 engine.

Epps Monoplane. The Epps Monoplane. Aviation, vol. 20, no. 7, Feb. 15, 1926, p. 222, 2 figs. Details of high-wing monoplane, wing being attached on each side to upper fuselage longerons; it is single-place plane with cockpit between front and rear main wing spars.

Flying Boats. See FLYING BOATS.

Hawker. Hawker Single-Seater Fighters for Den-

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NOTE.—The abbreviations used in indexing are as follows:

Academy (Acad.)
American (Am.)
Associated (Assoc.)
Association (Assn.)
Bulletin (Bul.)
Bureau (Bur.)
Canadian (Can.)
Chemical or Chemistry (Chem.)
Electrical or Electric (Elec.)
Electrician (Elecn.)
Engineer (Engr.[s])
Engineering (Eng.)
Gazette (Gaz.)
General (Gen.)
Geological (Geol.)
Heating (Heat.)
Industrial (Indus.)
Institute (Inst.)
Institution (Instn.)
International (Int.)
Journal (Jl.)
London (Lond.)
Machinery (Machy.)
Machinist (Mach.)
Magazine (Mag.)
Marine (Mar.)
Materials (Matls.)
Mechanical (Mech.)
Metallurgical (Met.)
Mining (Min.)
Municipal (Mun.)
National (Nat.)
New England (N. E.)
Proceedings (Proc.)
Record (Rec.)
Refrigerating (Refrig.)
Review (Rev.)
Railway (Ry.)
Scientific or Science (Sci.)
Society (Soc.)
State names (Ill., Minn., etc.)
Supplement (Supp.)
Transactions (Trans.)
United States (U. S.)
Ventilating (Vent.)
Western (West.)

mark. Flight, vol. 18, no. 3, Jan. 21, 1926, pp. 30–33, 9 figs. Details of Danecock type for Danish government, tests of which give very good all-round performance; design of Danecock has been evolved from that of the Woodcock; equipped with Armstrong-Siddeley Jaguar engines.

Latécoère. The Latécoère Multi-Engine Bomber. Aviation, vol. 20, no. 6, Feb. 8, 1926, p. 184, 1 fig. Designed with view to its being able to withstand total disablement by shell fire; officially known as L.A.T. 6; equipped with Salmson 265-hp. engines; speed, 122 m.p.h.

Multiple-Engine. Multi-Engine Airplanes and Forced Landings, H. G. Smith. Aviation, vol. 20, no. 3, Jan. 18, 1926, p. 78. Points out that multiple engines insure greater reliability; one forced landing in 343,000 flights or one in 1400 years, a possibility.

Passenger and Freight. The "Mercury" Standard 6W-3. Aviation, vol. 20, no. 5, Feb. 1, 1926, p. 150, 2 figs. Five-place passenger and freight plane produced at low price.

Scale Effect. The Air Forces on a Model of the Sperry Messenger Airplane without Propeller, M. N. Munk and W. S. Diehl. Nat. Advisory Committee for Aeronautics—Report, no. 225, 1925, 12 pp., 9 figs. Report on scale-effect research made in wind tunnel of National Advisory Committee of Aeronautics with a 1/10 scale model of Sperry Messenger airplane with U.S.A.-5 wings showing that scale effect is almost confined to the drag.

Wings. Minimum Resistance of Wings with Rectilinear Generatrices (Résistance minimum des ailes à génératrices rectilignes), M. R. Pris. Aérophile, vol. 33, no. 21–22, Nov. 1–15, 1925, pp. 330–333, and vol. 34, no. 1–2, Jan. 1–15, 1926, pp. 13–17, 9 figs. On basis of Joukowski-Prandtl theory author discusses induced supplementary resistance, frictional resistance, resistance of profile.

Wright Apache Shipboard. The Wright Apache Shipboard Fighter. Aviation, vol. 20, no. 5, Feb. 1, 1926, p. 147, 1 fig. High-speed pursuit type with Wright Simoon air-cooled engine which develops 325 to 350 hp.; performance data.

AIRSHIPS

Keels. Adjustment of the Elastic Properties of a Model Keel, United States Army Airship RS-1, W. Hovgaard. Mathematics & Physics—Jl., vol. 5, no. 1, Dec. 1925, pp. 8–39, 12 figs. Design and construction of RS-1; development of formulas for calculating deflections of keel; construction and adjustment of the model keel; summary of test results with keel alone, envelope alone and complete model.

Metalclad. Metalclad Rigid Airship Development, R. H. Upson. Soc. Automotive Engrs.—Jl., vol. 18, no. 2, Feb. 1926, pp. 117–131, 18 figs. States that Metalclad airship is last step in development of rigid airship and must be adopted if such a means of transportation is to be made available both for arms of national defense and for commercial purposes; comparison of metal and fabric; transverse shape of envelope; general formulas for hull stresses; comparison of stability and control; resistance as affected by fineness ratio; data on water model of MC-2. Bibliography.

Mooring Towers. 210-Ft. Airship Mooring Tower at Detroit Airport, H. V. Thaden. Eng. News-Rec., vol. 96, no. 5, Feb. 4, 1926, pp. 202–204, 3 figs. With new system, dirigible lands passengers and freight at ground instead of at top of tower; bow held in sliding guide as ship is hauled down; anchor trucks restrain ship's hull.

Zeppelin. The Safety of the Zeppelin Airship, E. A. Lehmann. Mech. Eng., vol. 48, no. 2, Feb. 1926, pp. 115–118. Survey of possible dangers and risks that might be encountered by airship of Zeppelin type, and of means of overcoming or avoiding them; data on careers of 115 airships constructed by German Zeppelin Co.; general conclusion is that with present status of Zeppelin engineering and granted a properly educated and conscientious operating personnel, there is very little probability of any further losses of Zeppelin airships in future.

ALLOYS

Aluminum. See ALUMINUM ALLOYS.

Brass. See BRASS.

Viscosity. Viscosity of Alloys at High Temperatures (Contribution a l'étude de la viscosité des alliages à temperature élevée), J. Cournot and K. Sasagawa. Revue de Métallurgie, vol. 22, no. 12, Dec. 1925, pp. 753–763, 9 figs. Describes apparatus for determining rapidly and with sufficient accuracy speed of hot pouring and limits of viscosity at various temperatures.

ALUMINUM ALLOYS

Aluminum-Zinc. Study of the Aluminum-Zinc System, O. Tiedemann. Zeit. für Metallkunde, vol. 18, no. 1, Jan. 1926, pp. 18–21, 7 figs. Examination of aluminum-zinc alloys with 0 to 20 per cent zinc content after different heat treatments; showing new equilibrial relations in a part of diagram of state, heretofore regarded as field of mixed crystals.

Casting. The Casting of Aluminium Alloys. Chem. Age (Lond.), vol. 14, no. 342, Jan. 2, 1926, p. 3. Practical notes on process; preparation of alloy.

Commercial. Commercial Aluminium Alloys from the Users' Point of View, J. B. Hoblyn. Foundry Trade Jl., vol. 33, no. 490, Jan. 7, 1926, pp. 3–5, and (discussion), no. 491, Jan. 14, 1926, pp. 34–36. Investigation of how far results obtained experimentally from casting made under favorable conditions were reproduced in practice; in author's belief, there is a future for heat-treated aluminum alloys in automobile construction; in stressed parts, castings, if heat treated, have very extensive field. (Abstract.)

Duralumin. See DURALUMIN.

Heat Treatment. Thermal Refining of Aluminum Alloys (Die Entwicklung des Problems der thermischen Vergütung technischer Aluminiumlegierungen), P. Assmann. Metall und Erz, vol. 22, no. 20, Oct. 2, 1925, pp. 506–511, 1 fig. Development and recent theories of heat treating, segregation and mixed crystals; concludes that although great interest is taken in questions, there are so far no definite results, due to contradictory hypotheses.

Light Casting. Aluminum Alloys Develop Greater Commercial Applications, E. V. Pannell. Foundry, vol. 54, no. 3, Feb. 1, 1926, pp. 105–107. Presents list showing average analysis and approximate physical properties of 67 alloys which are of more or less commercial value.

Soldering Castings. Repairing Aluminum Alloy Castings by Soldering, A Eyles. Machy. (N. Y.), vol. 32, no. 6, Feb. 1926, pp. 485–486. Failure caused by corrosion; heat for soldering; cause of corrosion; composition of aluminum solder; tinning surfaces to be joined; tensile strength of solder; salvaging new castings; repairing broken castings.

AMMUNITION

Season Cracking in. Season Cracking in Small Arms Ammunition, N. H. Murdza. Army Ordnance, vol. 6, no. 34, Jan.-Feb. 1926, pp. 269–272, 8 figs. Causes of season cracking or characteristic splitting occurring in non-ferrous alloys especially of copper-zinc series for cartridge cases, i. e., initial strains due to cold work, severe construction resulting from over-size bullets or under-size neck diameters, etc.; localized or general pitting due to acids, alkaline, gaseous or atmospheric corrosion.

APPRENTICES, TRAINING OF

Craftsmen. The Training and General Position of the Craftsman, K. C. Appleyard. Foundry Trade Jl., vol. 33, no. 491, Jan. 14, 1926, pp. 28–30, and (discussion), no. 492, Jan. 21, 1926, pp. 51–52. Fundamentals and history of craftsman; present position and future development; social and psychological factors; aspirations of craftsman; discontent and progress; choosing apprentice; artisan training.

Railway. The Training of Railway Apprentices, M. Chouard. Ry. Engr., vol. 47, no. 552, Jan. 1926, pp. 7–10, 2 figs. Details of apprenticeship system developed by Paris-Orleans Railway, which has produced very good results and has greatly increased efficiency of the mechanical engineering staff.

AUTOMOBILE ENGINES

Crankcase-Oil Dilution. A Suggested Remedy for Crankcase-Oil Dilution, R. E. Wilson and R. E. Wilkin. Soc. Automotive Engrs.—Jl., vol. 18, no. 2, Feb. 1926, pp. 163–170, 11 figs. Results of extensive tests to determine rate and extent of dilution for various types of car under various operating conditions; as remedy, authors suggest use of fairly heavy oil, of from 500 to 575-sec. viscosity at 100 deg. fahr., blended with from 10 to 12 per cent of distillate having boiling range substantially identical with that found in average crankcase oil at equilibrium.

Cylinder Blocks. Where Machine Equipment Does Double Duty, F. H. Colvin. Am. Mach., vol. 64, no. 9, Mar. 4, 1926, pp. 349 and 352. Methods used by Rickenbacker Motor Co. in machining cylinder blocks for both 6- and 8-cylinder engines on same machine.

Design Trend. Higher Compression Ratios a Feature of This Year's Engines, P. M. Heldt. Automotive Industries, vol. 54, no. 2, Jan. 14, 1926, pp. 50–54, 11 figs. Better understanding of laws of heat flow in combustion chamber, aluminum-alloy pistons and improved fuel are factors contributing to trend; many gear-type oil pumps now outside crankcase.

Lubrication. Engine Lubrication. Motor Transport (Lond.), vol. 42, no. 1091, Jan. 25, 1926, pp. 97–100, 7 figs. Discusses circulating splash or trough system, splash and pressure system and hollow crankshaft system, their merits and maintenance.

Relationships between Lubricating Systems and Engine Performance, T. E. Coleman and J. B. Fisher. Soc. Automotive Engrs.—Jl., vol. 18, no. 2, Feb. 1926, pp. 201–213, 19 figs. Facts relating to behavior of lubricating systems and conclusions that have been drawn from observation of systems which vary in their mechanical elements; conclusions have been checked carefully by tests on different types of engine.

Machining. Willys-Knight Production Methods, F. H. Colvin. Automotive Production, vol. 64, no. 7, Feb. 18, 1926, pp. 263–265, 11 figs. Roughing out eccentric shafts on a gear hobber with eccentric milling cutters; finish turning all throws at once on special lathe.

Sleeve Manufacture. Willys-Knight Production Methods, F. H. Colvin. Am. Mach., vol. 64, no. 6, Feb. 11, 1926, pp. 229–233, 15 figs. Problems involved in making thousands of cast-iron sleeves, approximately 18 in. thick and 10 in. long, and having uniformly small tolerances.

Sleeve-Valve. Sleeve-Valve Engine Development, W. Ferrier Brown. Automobile Engr., vol. 16, no. 211, Jan. 1926, pp. 18–25, 14 figs. Outlines development of sleeve-valve engine and shows steady progress made with this type from its inception in 1908 to its present state.

Starting. Progress Report on Engine-Starting Tests, J. O. Eisinger. Soc. Automotive Engrs.—Jl., vol. 18, no. 2, Feb. 1926, pp. 147–152, 12 figs. Supplements previous progress reports on coöperative fuel research and brings up-to-date the information on engine-starting tests made in past year; test apparatus gave starting results similar to standard carburetors; tests of fuels at various temperatures; fuels vary in amount vaporized; influence of low-boiling constituents; richness of mixture in cylinder determines starting time; fuel characteristics changed to suit temperature conditions.

Steam Cooling. Cylinder-Temperature Control by Evaporation, A. G. Herreshoff. Soc. Automotive Engrs.—Jl., vol. 18, no. 2, Feb. 1925, pp. 153–159, 9 figs. Advantages of fixed temperature of 212 deg. fahr. are: reduced piston friction, better vaporization, elimination of crankcase-oil dilution and prevention of rusting, thereby increasing life of engine; method of determining cylinder-wall temperatures; comparison of temperatures for water and for steam cooling under various operating conditions shows that, with steam cooling, hot spots are no hotter and cooler parts of cylinder have more nearly uniform higher temperature; describes Rushmore steam-cooling system, and predicts that engines of future will be steam cooled and covered with insulating jacket.

AUTOMOBILE FUELS

Equilibrium Boiling Points. Equilibrium Boiling Points, W. A. Whatmough. Indus. & Eng. Chem., vol. 18, no. 1, Jan. 1926, pp. 43–45, 2 figs. Equilibrium boiling points of motor fuels have been investigated by Barnard and Wilson, and, independently, by writer in connection with new system of dry-gas carburation, which involves boiling fuel before its admixture as dry gas with air.

Synthetic. Synthetic Motor Fuels—Has Europe Found the Formula? W. Ostwald. Automotive Industries, vol. 54, no. 3, Jan. 21, 1926, pp. 108–110. Author claims there is no longer any doubt as to chemists' ability to produce quality heat units from cheap materials and only question now is how it can be done to best advantage. Translated from Motorwagen.

AUTOMOBILE MANUFACTURING PLANTS

Labor and Materials Saving. Buick Saves $3,500,000 in Nine Months, W. W. Clark, Jr. Mfg. Industries, vol. 11, no. 2, Feb. 1926, pp. 85–88, 2 figs. Intensive study of labor, materials and scrap has good results; reduction of working force brought about through installation of up-to-date equipment and methods, and numerous changes in machines and in methods of handling stock, materials and scrap.

Maxwell, Detroit. Efficiency Methods in the Maxwell Plant, C. O. Herb. Machy. (N. Y.), vol. 32, no. 6, Feb. 1926, pp. 463–466, 9 figs. Operations on driving shafts, bevel gears, axle housings, differential cases and cylinders; sherardizing; testing engines; checking up delays in assembly line.

AUTOMOBILES

Bodies. Show Reveals Many Interesting New Trends in Body Design, K. W. Stillman. Automotive Industries, vol. 54, no. 2, Jan. 14, 1926, pp. 43–49, 10 figs. General tendency is toward narrower body pillars; D-shaped rear quarter windows are numerous; many collapsible tops.

Brake-Testing Machine. Cowdry Brake Testing Machine Adapted for Production Work, W. L. Carver. Automotive Industries, vol. 54, no. 6, Feb. 11, 1926, pp. 223–224, 1 fig. Redesign of apparatus makes it suitable for use in automobile plants; structural-steel trestle with four pairs of rolls and electrically driven dynamometer, chief features of construction.

Brakes. Adex Four-Wheel Brake (Die "Adex"-Vierradbremse), Automobil-Rundschau, vol. 27, no. 12, Dec. 1, 1925, pp. 273–276, 3 figs. Development of front-wheel brakes and of four-wheel brakes in which entire adhesive weight of automobile is used in braking action; describes design and construction of Adex brakes, together with basic patterns.

An Arresting Brake. Autocar, vol. 56, no. 1579, Jan. 22, 1926, pp. 138–140, 3 figs. Dewandre vacuum four-wheel brake that will arrest a car weighing 2½ tons to a dead stop from road speed of 40 mi. per hr. in distance of less than 20 yds., its object being to assist driver to apply brakes, relieving him of greater part of work.

Causes and Prevention of Squeaking Brakes, F. C. Stanley. Soc. Automotive Engrs.—Jl., vol. 18, no. 2, Feb. 1926, pp. 160–162, 1 fig. Theory was formulated that brake squeaking is undamped or unmuffled vibration of drum caused by plowing action of metal or grit in lining; preventive measures; service-station methods of overcoming squeaking brakes.

Brakes, Four-Wheel. Four Wheel Brakes. Automobile Engr., vol. 16, no. 211, Jan. 1926, pp. 12–14, 5 figs. Novel coupling principle developed by Rudge-Whitworth, Ltd.

Chassis Design. New Cars Reflect Tendency to Build Chassis Closer to Ground, H. Chase. Automotive Industries, vol. 54, no. 2, Jan. 14, 1926, pp. 54–57, 6 figs. Supplementary parts are fitted with greater care than formerly; centralized lubricating systems used on more models.

Development. The Future of the Motor Car, A. H. Burgoyne. Roy. Soc. Arts.—Jl., vol. 74, no. 3815, Jan. 1, 1926, pp. 142–160. Discusses development as affecting road transportation; tendencies in engine design, traffic regulations, etc.

Headlights. What Happens When an Automobile Headlight Is Out of Focus, L. C. Porter and G. F. Prideaux. Soc. Automotive Engrs.—Jl., vol. 18, no. 2, Feb. 1926, pp. 222–231, 13 figs. Study to secure data that would emphasize necessity of accurate control of size and location of light source with respect to focal point of parabolic headlight reflectors; describes testing equipment and gives results of tests.

Machining of Parts. How the Ajax Transmission Case is Made, C. O. Herb. Machy. (N. Y.), vol. 32, no. 7, Mar. 1926, pp. 523–526, 8 figs. Production methods used in plant of Ajax Motors Co., Racine, Wis., recently equipped throughout with new machines and tools.

New York Shows. Statistical Picture of Ten New York Shows. Automotive Industries, vol. 54, no. 2, Jan. 14, 1926, p. 53. Gives total number of exhibitors and number of vehicles exhibited, body styles, engine characteristics, wheels, brakes and balloon tires, at New York shows since 1917.

Renault. The 13.9 H.P. Renault. Auto-Motor Jl., vol. 31, no. 3, Jan. 21, 1926, pp. 55–58, 10 figs. Describes four-cylinder model with 75 mm. bore 120 mm. piston travel; engine will develop 23 hp. at 2400 r.p.m.; four-wheel braking, etc.

Triumph. The 15–50 H.P. Triumph. Auto-Motor Jl., vol. 31, no. 4, Jan. 28, 1926, pp. 75–78, 13 figs. Equipped with 4-cylinder engine with detachable head; piston travel 115 mm., bore 77.5 mm., giving displacements of 2169 cc.; single-plate-type clutch; three forward speeds with one reverse.

AVIATION

Aerial Navigation. Progress Necessary to Develop Aerial Navigation (Les Progrès Techniques sont nécessaires au développement de la Navigation Aérienne), E. Allard. Assn. des Ingenieurs sortis de l'Ecole Polytechnique de Bruxelles—Bul. Technique, vol. 21, no. 2, 1925, pp. 33–44, 5 figs. Records attained since Blériot crossed English Channel; problems of safety, economy, metals for airplanes, fuels.

Night Flying. Night Flying Experiments in Europe. Aviation, vol. 20, no. 6, Feb. 8, 1926, pp. 182–183, 1 fig. London-Paris airway lighted; experiments with neon lights and radio direction finding; fog difficulties.

B

BALANCING MACHINES

Flywheel. New Machine Designed to Determine Unbalance of Flywheels. Automotive Industries, vol. 54, no. 6, Feb. 11, 1926, pp. 230–231, 3 figs. Axial and radial planes of unbalance found by mechanism of Tinius Olsen Testing Machine Co.; apparatus also developed for balancing disk wheels and for testing Brinell hardness.

BEARINGS

Oil Film in. Charts for Studying the Oil Film in Bearings, Geo. B. Karelitz. Mech. Eng., vol. 48, no. 2, Feb. 1926, pp. 128–131, 5 figs. Presents charts which give designer or investigator a means of determining with sufficient accuracy the shape and pressures in oil film for bearings under different conditions.

BEARINGS, ROLLER

Timken. Timken Roller Bearings in Railway Operation and Conveying (Timken-Rollenlager im Eisenbahnbetrieb und Förderwesen), G. Buhle. Glasers Annalen, vol. 49, no. 11, Dec. 1, 1925, pp. 209–214, 15 figs. Introduction of Timken in Germany by Linke-Hofmann-Lauchhammer Co. for rail traction, design of wheels and axle sets for mine cars.

BOILER FEEDWATER

Treatment. Fundamentals in the Conditioning of Boiler Waters. R. E. Hall. Engrs.' Soc. of Western Penn.—Proc., vol. 41, no. 9, Dec. 1925, pp. 347–377, 14 figs. Relation of water softening to boiler-water conditioning; deposits resulting from evaporation or natural waters; mechanism of scale formation and means of obviating it; boiler-water sludges and steam-line deposits, control of suspended material and wet steam and non-condensible gases in steam.

Permutite Feedwater and Siliceous Boiler Scale (Permutiertes Speisewasser und siliziumhaltiger Kesselstein), Pfadt. Zeit. Bayerischen Revisions-Vereins, vol. 29, no. 22, Nov. 30, 1925, pp. 240–242. Discusses a case of inward bulging of fire tubes presumably due to boiler scale; analysis of scale and water; contradictory views on separation of silicic acid from alkaline feedwater. See also article by K. Braungard, in no. 24, Dec. 31, 1925, pp. 259–261, describing conditions under which formation of siliceous scale may be avoided.

Pure Feed Water, D. G. McNair. Power Engr., vol. 21, no. 238, Jan. 1926, pp. 23–25. Deaerators and their functions; evaporators; advantages of multiple effect; preheaters, coils and straight tubes.

Purification of Water for Industrial Use (L'Epuration des Eaux destinées aux Usines), F. Collin. Vie Technique & Industrielle, vol. 7, no. 74, Nov. 1925, pp. 94–96. Formation of boiler scale; treatment with lime, soda, permutite, etc., as means of prevention.

BOILER FURNACES

Air Preheaters. Increasing Importance of Preheating Air of Combustion for Boiler Plants (Die zunehmende Bedeutung der Vorwärmung der Verbrennungsluft bei Feuerungsanlagen für Dampfkessel), F. Wintermeyer. Feuerungstechnik, vol. 14, no. 5, Dec. 1, 1925, pp. 49–52, 6 figs. Design and arrangement of preheaters; AEG, Ljungström and German Babcock and Wilcox types; comparison with economizers; advantages of preheating, especially with pulverized coal.

Preheating Air of Combustion for Steam Boilers (Die Vorwärmung der Verbrennungsluft bei Dampfkesseln), B. Schulz. Wärme, vol. 48, no. 52, Dec. 25, 1925, pp. 660–662. Patents and design of preheaters; operating experience; British and American efficiency tests.

Arches. Suspended Furnace Arches for Bagasse Furnaces. Int. Sugar Jl., vol. 27, no. 324, Dec. 1925, pp. 661–663, 2 figs. Discusses function of furnace arch, flat suspended arches, advantages of Liptak arches, their durability, etc.

Brown-Coal-Fired. Steam Raising Plant at Yallourn, Vic. Commonwealth Engr., vol. 13, no. 4, Nov. 2, 1925, pp. 139–141, 3 figs. Details of John Thompson water-tube boilers fired with brown coal at power station of the Victorian Electricity Commission, each boiler guaranteed to evaporate 70,000 lb. of water per hour; test carried out with brown coal containing 48 per cent moisture showed maximum of 105,000 lbs. per hour and efficiency of 77.3 per cent, stokers burning 98 lb. of coal per sq. ft. on grate area.

Cleaning Grates. Clinker-Removing Devices for Boilers (Abschlackvorrichtungen für Dampfkessel), W. Benedict. Gesundheits-Ingenieur, vol. 48, no. 49, Dec. 5, 1925, pp. 617–619, 4 figs. Various types of devices; dumping and tipping grates, revolving grates, etc.; combustion diagrams with and without cleaning grates.

Combustion Control. Combustion Control System Reduces Labor. Blast Furnace & Steel Plant, vol. 14, no. 1, Jan. 1926, p. 47. Describes system which saved $4359.04 a year in wages, and also increased boiler efficiency appreciably.

Efficiency, Increasing. Modern Ways of Increasing Power Plant Furnace Efficiency, F. Juraschek. Indus. Mgmt. (N. Y.), vol. 71, no. 2, Feb. 1926, pp. 119–124, 7 figs. Describes recent methods used to cut down loss of efficiency at furnace; growing popularity of pulverized coal; development of water-cooled furnace wall; utilization of waste heat for flue gases to preheat air for furnace combustion.

European. Fuels and Furnaces in Europe, W. Trinks. Fuels & Furnaces, vol. 4, no. 1, Jan. 1926, pp. 19–30 and 36, 22 figs. Developments noted by author on recent trip; high-temperature and low-temperature carbonization; liquefaction of coal; materials handling; heating furnaces; sheet furnaces; welding, atmosphere control, etc.

Oil-Fired. Systems for Burning Liquid Fuel. Southern Power Jl., vol. 44, no. 1, Jan. 1926, pp. 39–47, 18 figs. Design of oil burning furnaces, advantages and drawbacks of oil firing, circulation and heating of oil, types of oil burners, operating costs, etc.

Producer-Gas-Fired. A Producerg-Gas Fired Boiler. Engineer, vol. 141, no. 3658, Feb. 5, 1926, p. 163, 1 fig. Boiler with self-contained gas-producer furnace constructed and erected for experimental purposes in works in Tafford Park by Wollaston Gas Producers.

Radiation in. Radiation in Boiler Furnaces, B. N. Broido. Mech. Eng., vol. 48, no. 2, Feb. 1926, pp. 133–137 and (discussion) 137–138, 4 figs. Analysis of fundamentals of radiation and of effect of water-cooled walls on gas temperatures in furnace; gives curves showing relation between amount of fuel burned, surface exposed to direct radiation in furnace, and total heat absorbed for this surface, and standard curve is drawn which enables designer to determine with sufficient accuracy what part of total heat generated in furnace at different ratings is absorbed by water-cooled walls; curve can also be used to find heat transmission by radiation per sq. ft. of heating surface for any given conditions of furnace; effect of radiation from gases on heat transmission, and influence of radiation upon measurement of gas temperature.

Wall Design. Refractories for Boiler Furnace Walls, H. C. Thayer. Power Plant Eng., vol. 30, no. 4, Feb. 15, 1926, pp. 256–257, 4 figs. Designs of furnace walls which overcome difficulties due to expansion and contraction of firebrick under influence of temperature changes, etc.

BOILER OPERATION

Draft Regulation. Draft Regulator for Boiler Characterized by Introduction of Secondary Arc into Stack (Zugregler für Feuerungsanlagen, gekennzeichnet durch Einsteuerung von Nebenluft in den Rauchfuchs oder Schornstein), W. Seelig. Gesundheits-Ingenieur, vol. 48, no. 48, Nov. 28, 1925, pp. 607–609. Discusses Kraus differential minimum draft regulator and shows that same object may be attained by simpler and cheaper means and without danger of CO poisoning.

Valve Control. Motor Control for Valves, C. J. Sittinger. Elec. World, vol. 87, no. 4, Jan. 23, 1926, pp. 201–202, 2 figs. Montaup Elec. Co. uses central control system for closing boiler valves at Somerset station; emergency system provided.

BOILER PLANTS

Fuel Measurement for Tests. Fuel Measurement for Boiler Tests, D. S. Frank. Power Plant Eng., vol. 30, no. 3, Feb. 1, 1926, pp. 200–201, 2 figs. Simple yet accurate apparatus for weighing coal or oil, constructed at small cost.

Heat Losses. Heat Losses in Boiler Plants with Special Reference to Losses in Flue Gases and Their Reduction (Ueber Wärmeverluste in Dampfkesselanlagen under besonderer Berücksichtigung des Abgasverlustes und seine Verminderung), C. Rühl. Wärme- u. Kälte-Technik, vol. 27, no. 21, Nov. 1, 1925, pp. 229–234, 9 figs. Traces various kinds of losses and calculates those in fuel gases; use of economizers, calculation of efficiency and profitability.

BOILER PLATE

Metallurgical Problems. The Metallurgical Aspects of Modern Boiler Practice, L. P. Sidney. Chem. Age (Lond.), vol. 14, no. 342, Jan. 2, 1926, pp. 2–3. Factors of problem; boiler pressures and temperatures; elasticity and viscous flow; determinations of flow; chromium and nickel in boiler plates.

Stress Calculation. The Strength of Axially Symmetrical Vessels, with Particular Reference to Steam Boilers (Ueber die Festigkeit achsensymmetrischer Schalen, insbesondere von Dampfkesseln), J. Geckler. Zeit. des Vereines deutscher Ingenieure, vol. 70, no. 5, Jan. 30, 1926, pp. 163–168, 8 figs. Points out that purely static calculation of cupolas, boilers, containers, pipes, etc., becomes inadequate when deflections occur; it is then necessary to take elastic deformation into consideration; approximative method of calculation is developed and its application to calculation of boiler stresses described.

BOILER TUBES

Failures. Why Boiler Tubes Burnt Out, Geo. C. Reinhard. Power, vol. 63, no. 2, Jan. 12, 1926, pp. 51–53, 3 figs. Removal of scale resulted in tube failure; scientific study made of conditions; trouble due to sulphur in oil.

BOILERS

Electrically Heated. Central Heating Plant by Means of Electric Boilers of Lyons Gas Co. (L'installation de chauffage central par chaudières électriques de la Compagnie du Gaz de Lyon), D'Aubenton-Carafa. Electricien, vol. 56, no. 1384, Nov. 15, 1925, pp. 512–514, 4 figs. Design and operation of boilers heated by current during low load (mainly night time) calculated to maintain a temperature of +18 deg. cent. for 10½ hours per day with outside temperature at —10 deg. cent.; steam accumulators of 30 cu. m., one each boiler; pipe lines of 1600 m.

Economic Investigation of Electrode Boiler Plants (Wirtschaftliche Untersuchungen von Elektroden-Kesselanlagen), M. A. Nüscheler. Zeit. Bayerischen Revisions-Vereins, vol. 29, nos. 23 and 24, Dec. 15 and 31, 1925, pp. 247–250, 257–259, 4 figs. Discusses results of tests with Sulzer and Revel electrode boiler plants; concludes that detailed and thorough study is required before large amounts of capital are invested in this branch.

Flange Failures. Flange Failures (Krempenanbrüche), Zeit. des Bayerischen Revisions-Vereins, vol. 29, nos. 22, 23 and 24, Nov. 30, Dec. 15 and 31, 1925, pp. 239–240, 245–247 and 255–257, 6 figs. Discusses damage to boiler and boiler explosions due to flange failures; legal specifications as to calculation of heads; cause of failures; proposed new regulations.

Fuel-Waste Estimation. Insufficient Data for Estimating Fuel Waste, H. D. Fisher. Power Plant Eng., vol. 30, no. 3, Feb. 1, 1926, pp. 218–220. Points out that fuel-gas temperature, soot on tubes and carbon in ash are entirely overlooked by F. C. DeWeese in his investigation of a poorly run boiler plant, described in Nov. 15, 1925, issue of same journal.

Heads. Most Favorable Shape of Dished Boiler Heads (Ueber die günstigste Form der Meridianlinie gewölbter voller Kesselböden), W. Otte. Zeit. des Bayerischen Revisions-Vereins, vol. 29, no. 22, Nov. 30, 1925, pp. 237–238, 3 figs. Calculation of new shape of dished heads, in place of elliptic, having equal main axes and a larger flange radius with a smaller radius of curvature.

High-Pressure. High-Pressure Boilers (Hochdruckkessel), P. Fischer and K. Schleip. Feuerungstechnik, vol. 14, nos. 2, 3 and 4, Oct. 15, Nov. 1 and 15, 1925, pp. 13–15, 27–30 and 39–42, 22 figs. Discusses material for constructing high-pressure boilers; properties of ingot iron and nickel alloy steels; behavior at high temperatures; aging and recrystallization; examples of seamless boiler shells for up to 110-atmos. pressure; formulas for boiler calculation and additional stresses in boiler operation, with examples; proposals for calculating plate thickness; production of seamless high-pressure boilers, calculation of boiler shells and suitability of present formulas.

High-Pressure Vertical Boiler Plants (Hochdruck-Steilrohrkesselanlagen), H. F. Lichte. Wärme, vol. 48, nos. 48, 49 and 50, Nov. 27, Dec. 4 and 11, 1925, pp. 601–607, 617–622 and 634–637, 40 figs. Discusses design and operation of various types of Steinmüller and other vertical boilers, division and length of tubes, heating surface, combustion chamber, heat exchangers, water circulation, suspension of boilers, clusters of tubes with bent and straight tubes, soot blowers, superheated steam regulators, waste-heat boilers.

High-Pressure Vertical Boiler Plants for Wood, Heat and Lignite Firing (Hochdruck-Steilrohrkesselanlagen für Holz, Torf- und Braunkohlenfeuerung), H. F. Lichte. Braunkohle, vol. 24, no. 36, Dec. 5, 1925, pp. 799–803, 4 figs. Development of various types by Hanomag; details of design and construction.

Internal-Combustion. The Internal-Combustion Boiler, O. Brunler. Inst. Mar. Engrs.—advance paper for mtg. Nov. 24, 1925, 6 pp., 5 figs. Details of internal-combustion boiler, principle of which is to maintain flame burning in water in order to produce steam; application to generator which can produce 11,000 lb. of steam-gas mixture per hour.

Locomotive. See LOCOMOTIVE BOILERS.

Water-Tube. See BOILERS, WATER-TUBE.

BOILERS, WATER TUBE

Oil-Fired. Handling Oil-Fired Water-Tube Boilers, Geo. H. Briggs. Power, vol. 63, no. 4, Jan. 26, 1926, pp. 130–131. Problems encountered; proper air regulation; damper control.

BOLTS

Manufacturing and Stocking. Manufacturing and Stocking Bolts in the Shop, E. Kennedy. Ry. Mech. Engr., vol. 100, no. 1, Jan. 1926, pp. 56–57, 2 figs. Notes on establishing a system for manufacturing and stocking of finished bolts.

BOXES

Shipping Containers. Saving Money on Shipping Containers. Mfg. Industries, vol. 11, no. 2, Feb. 1926, pp. 129–130, 4 figs. Specific points and requirements to consider.

BRASS

Heat Treatment. Annealing, Tempering and Drawing of Some Industrial Nickel-Brasses (Le recuit, la trempe et le revenu de quelques laitons au nickel industriels), F. M. Ostroga. Revue de Métallurgie, vol. 22, no. 12, Dec. 1925, pp. 776–786, 16 figs. Concludes that it is always possible to secure hardening corresponding to annealed state of metal by means of tempering with or without drawing; hardness is the more pronounced the finer the new microstructure.

Ingot Production. The Production of Sound Brass and Copper Ingots. Metal Industry (Lond.), vol. 28, no. 1, Jan. 1, 1926, pp. 3–7. General discussion of practical problems at meeting of Birmingham and West Midlands Section of Inst. of Metals, dealing with

mold dressings, mold materials, pouring temperatures and speeds, cooling rates, feeding, casting and melting equipment, manual skill, etc.; comparisons of British, European Continental and American practice.

Melting and Pouring. Melting and Pouring of Brass and Bronze, T. J. Bamford. Foundry Trade Jl., vol. 33, no. 493, Jan. 28, 1926, pp. 76–78. Utilization of scrap metal; aluminum as an impurity; using turnings and borings; melting furnaces. Includes discussion and author's reply.

BRASS FOUNDRIES

Tumblers for Castings. Tumblers for Brass Castings. Foundry Trade Jl., vol. 32, no. 488, Dec. 24, 1925, p. 526. Discusses use of tumbling barrel as cleansing factor; tumbling consists of filling or partially filling barrels with castings, cleansing material and sometimes liquid; shapes and materials employed in making tumblers; loading tumblers.

BROACHING MACHINES

Hydraulic. American Hydraulic Broaching Machines. Machy. (N. Y.), vol. 32, no. 6, Feb. 1926, pp. 505–506, 3 figs. Details of three broaching processes which are operated hydraulically; made by Am. Broach & Machine Co., Ann Arbor, Mich.

C

CABLEWAYS

Funicular. The Aiguille du Midi Funicular Aerial Line (Le funiculaire aérien de l'Aiguille du Midi), A. Bourgain. Nature (Paris), no. 2697, Dec. 12, 1925, pp. 373–380, 12 figs. Layout and construction of line from Pèlerins to Paraz and finally to Midi (near Mount Blanc, Switzerland), of 3842-m. altitude, of which the first section has recently been opened to traffic; three-cable system; cars equipped with electric motors of 55 to 70 kw.

CAMS

Milling. Use of Dividing Head and Circular Attachment for Cam Milling, H. W. Cable. Machy. (N. Y.), vol. 32, no. 6, Feb. 1926, pp. 481–482, 2 figs. Describes use of barrel type of indexing cam when applied to rotary table of station or indexing type of automatic machine.

CAR COUPLERS

Automatic. Japanese Railways Adopt Automatic Couplers, S. Akiyama. Ry. Mech. Engr., vol. 100, no. 1, Jan. 1926, pp. 30–34, 6 figs. Final work of changing from screw and link type to automatic is completed in one day.

Vienna Tests New Coupler. Elec. Traction, vol. 22, no. 1, Jan. 1926, pp. 31–32, 4 figs. New system of automatic train and current coupling being tested in Vienna, Austria.

CARS, PASSENGER

Parlor. Official Saloon Coach, Buenos Ayres & Pacific Railway. Ry. Gaz., vol. 44, no. 3, Jan. 15, 1926, p. 93, 3 figs. Special car built at Junin shops in Argentine Republic; length, 82 ft.; contains day saloon, dining saloon, bedrooms, kitchen, etc.

CARS, REFRIGERATOR

Fruit. Fruit Refrigerator Cars for D. L. & W., A. Alquist. Ry. Mech. Engr., vol. 100, no. 1, Jan. 1926, pp. 27–29, 3 figs. Insulated and ventilated to afford protection in cold and hot weather; Am. Ry. Assn. standards closely followed.

CAST IRON

Analysis. The Rapid Determination of Structural or Constitutional Analysis, J. E. Fletcher and J. G. Pearce. Brit. Cast Iron Research Assn.—Bul., no. 11, Jan. 1926, pp. 17–20, 6 figs. Gives rapid method of determining structural analysis, results being sufficiently close to accuracy for normal purposes; method is illustrated by case of ordinary gray iron of cylinder quality, and in general method applies to gray irons in which there is reasonable manganese content, and in which combined carbon is such as to give no free cementite (iron carbide), as is normally the case.

Diesel-Engine. Cast Iron for Diesel Engines, A. Campion. North-East Coast Instn. Engrs. & Shipbldrs.—advance paper, for mtg. Jan. 22, 1926, pp. 201–216, 10 figs. Discusses special conditions of temperature and stress obtaining in oil-engine practice, and their effect upon strength, growth, hardness and structure; importance of metallurgical aspect; deals with general metallurgical principles which have to be applied in determining type of iron to be used for different parts of engine, and with factors concerned in production of metal having power of retaining its strength at maximum temperature which may be developed, that will not change in shape and size after limited period of service, and that will resist abrasion and wear by action of piston rings; influence of temperature; requirements as regards constitution and structure.

Factors and Problems. Some Factors which Constitute Problems in the Iron Foundry, S. G. Smith. Foundry Trade Jl., vol. 33, no. 492, Jan. 21, 1926, p. 42. Stresses importance of freezing phenomena, volume changes, solid contraction, etc.; distortion is direct result of contraction; examples of effect of mass on shrinkage; importance of correct sand control. and of adequate liquid metal in risers to accomplish proper feeding. (Abstract.)

Graphite in. Graphite in Pig and Cast Iron. Metal Industry (Lond.), vol. 28, no. 2, Jan. 8, 1926, pp. 39–40, 1 fig. Discusses importance of effect on graphite of temperature to which iron is raised during smelting and remelting; refers to some of principal researches on subject, more particularly recent work of Piwowarski; importance of subject in connection with suggested reforms of pig-iron grading.

Gray, Liquid Shrinkage of. Liquid Shrinkage in Grey Iron, J. Longden. Foundry Trade Jl., vol. 33, no. 494, Feb. 4, 1926, pp. 85–92, 17 figs. Existing theories; defects due to what is known as Leonard effect; influence of dissolved gases; experimental data; influence of temperature on castings; graphite in molten cast iron; influence of length of cooling range; influence of slow pouring; filtering cast iron; rod feeding; chills and denseners; feeding heads.

Gray, Structure of. Compares Gray Iron Structure, Wm. Campbell. Foundry, vol. 54, no. 4, Feb. 15, 1926, pp. 148–149, 5 figs. Comparison between structure of gray iron cast in sand molds and cast-iron permanent molds cooled by oil. Abstract of report.

Pearlitic. Pearlitic Cast Iron (La fonte perlitique), B. Buffet and A. Roeder. Société Industrielle de Mulhouse—Bul., vol. 91, no. 9, Nov. 1925, pp. 622–634, 14 figs. Discusses qualities of good gray iron, machinable cast iron, pearlitic and steeled cast iron, graphitization, testing and uses.

Superheating. The Superheating of Cast Iron. Metallurgist (Supp. to Engineer, vol. 141, no. 3657), Jan. 29, 1926, pp. 15–16, 1 fig. Review of two papers by Piwowarski, published in Stahl u. Eisen, Aug. 27 and Dec. 3, 1925, relating to effect of superheating molten iron up to temperatures approaching 1800 deg. cent.; he shows that irons superheated at 1400 deg. cent., cast at 1200 deg., and subsequently annealed, yield more finely divided temper carbon than same irons which had only been heated to 1250 deg. during melting. Review also of work by Sauerwald and Wecker in Zeit. für anorganische Chemie, Nov. 10, 1925, with determinations of density of molten cast iron.

Test Bars. Criticize American Practice, L. Piedboeuf. Foundry, vol. 54, no. 2, Jan. 15, 1926, pp. 50–51. French and Belgian foundrymen discuss various types of cast-iron test bars at recent congress held in Liège, Belgium.

Thyssen-Emmel and Lanz-Perlit. Special Cast Irons—A Comparison of the Lanz Perlit and Thyssen-Emmel Processes, J. L. Francis. Metal Industry (Lond.), vol. 28, no. 4, Jan. 22, 1926, pp. 85–87, 5 figs. Brief description and comparison of the two processes; comparison of chemical composition, of graphite size, and distribution, and matrix structure; risk of defective results; concludes that facts go to show that Thyssen-Emmel is much the more promising of the two processes both in consideration of simplicity of operation and in requirements of specially designed plant.

CASTING

Green-Sand Molding. Wet Casting in Metal Foundries (Ueber Nassgiessen in der Metallgiesserei), A. F. Hager. Zeit. für die gesamte Giessereipraxis (Metall), vol. 46, no. 48, Nov. 29, 1925, pp. 205–206. Discusses advantages of casting metals and alloys in green sand molds.

Piano Frames. The Casting of Piano Frames (Einiges über das Giessen von Klavierrahmen), G. Krebs. Zeit. für die gesamte Giessereipraxis, vol. 46, no. 51–52, Dec. 23, 1925, pp. 573–575. Points out that material must be soft but possess high degree of strength; advantages of standardization; problems of molding and casting.

CASTINGS

Design. Casting Design, F. C. Edwards. Metal Industry (Lond.), vol. 28, no. 3, Jan. 15, 1926, pp. 61–64, 14 figs. By a few well-chosen examples, author illustrates molding and metallurgical problems that casting designer should take into consideration. (Abridged.) Paper presented before Sheffield Branch, Inst. Brit. Foundrymen. See also Foundry Trade Jl., vol. 33, no. 493, Jan. 28, 1926, pp. 65–68, 18 figs.

Economical Production. Cutting Down Waste on Castings, A. A. Wood. Iron Age, vol. 117, no. 7, Feb. 18, 1926, pp. 487–488, 2 figs. Reducing amount of metal and thus minimizing machining operations successfully practiced in many plants; in author's belief, excess finish is economic waste; large savings in plant of Warren Webster & Co., Camden, N. J., in cutting down patterns. (Abstract.) Paper read before Philadelphia Foundrymen's Assn.

Machines for Hollow. Casting Machines for Production of Hollow Castings such as Tubes (Machine à couler pour la fabrication de pièces de fonte à noyaux, telles que les tubes, etc.) Métallurgie et Construction Mecanique, nos. 50 and 51, Dec. 10 and 17, 1925, pp. 1675–1679 and 1715–1719, 13 figs. Details of machine in which formation of mold and core and their assembling is carried out automatically; machine after producing the core places it accurately in the mold produced simultaneously.

Weight Indication on Blueprints. Putting Casting Weights on Blueprints. Iron Age, vol. 117, no. 9, Mar. 4, 1926, pp. 631–632. Adoption of practice of indicating estimated weight of castings on blueprints sent to foundries for estimate; savings of $5,000,000 by eliminating duplicate work; committee formed to prosecute idea.

CENTRAL STATIONS

Budgeting Operation. Budgeting Central-Station Operation, H. P. Liversidge. Elec. World, vol. 87, no. 4, Jan. 23, 1926, pp. 189–191, 1 fig. Points out that budgets help keep balance among three dominating factors, engineering, financing and commercial activities; outlines their scope; details of their formulation and operation; measurement of success.

Control Boards. Power Station Control Boards, E. Zeuthen. Elec. Jl., vol. 23, no. 1, Jan. 1926, pp. 4–9, 7 figs. Details of advance in design for Toronto power station and Boardman substation of Ohio River Edison Co.; making switching practically fool-proof by suitable interlocking, facilitating real supervision by limiting panel equipment to essential instruments, segregating switchboards, etc.

France. The Comines Power Station, T. Rich. Elec. Rev., vol. 98, nos. 2511 and 2513, Jan. 8 and 22, 1926, pp. 59–60 and 125–127, 21 figs. Details of new station between Lille and Roubaix; two boiler houses with ten boilers, each having 1000 sq. m. of heating surface, using pulverized coal; overhead lines transmit 45,000 volts reduced to 10,500 at transformer stations.

Holyoke, Mass. Quarter-Century Evolution of Holyoke's Municipal Plant. Power, vol. 63, no. 9, Mar. 2, 1926, pp. 320–324, 11 figs. Development of generating station since 1902 when peak load was 400 kw.; it is now equipped with stoker-fired water-tube boilers, 5000-kva. and 10,000-kva. generating units, duplex drive for auxiliaries and modern coal-handling equipment; it supplies 15,954 customers in addition to lighting streets of city.

CHAIN DRIVE

Silent. Silent Chain Drives on Industrial Equipment, F. E. Gooding. Indus. Engr., vol. 84, no. 1, Jan. 1926, pp. 8–12, 8 figs. Discusses application in driving compressors, blowers and fans, conveyors, pulverizers, etc.

CHIMNEYS

Draft. Draft of Factory Chimneys (Le tirage des cheminées d'usines affranchi des influences atmosphériques), J. Vély. Électricien, vol. 56, no. 1383, Nov. 1, 1925, pp. 485–488, 3 figs. Describes Chanard system of vents at extremity of stack which turns harmful effects of wind into useful work and therefore assures a good draft in all kinds of atmospheric conditions.

COAL

Heating Value. A Simple Method for Determining Heating Value of Solid Fuels (Einige einfache Verfahren zur Bestimmung des Heizwertes fester Brennstoffe), H. Winkelmann. Brénnstoff- u. Wärmewirtschaft vol. 7, no. 24, Dec. 2, 1925, pp. 477–482. Method of taking samples approved by V. D. I. (Assn. of German Engrs.) and others; determining water content and ash content; describes von Jüptner process of calculation in which one gram of finely pulverized fuel is put into a platinum crucible and after determining moisture content, is heated until no more combustible gases escape.

Pulverized. See PULVERIZED COAL.

Purchasing. Economical Coal Buying, H. B. Stanton. Power, vol. 63, no. 4, Jan. 26, 1926, pp. 140–143. Points out shortcomings of purchasing on heat-unit basis and offers practical suggestions for selecting coal on performance basis; recommendations are directed especially to industrial plants.

Semi-Coking. Low-Temperature Semi-Coking Benefits Coal, R. D. Hall. Coal Age, vol. 29, no. 3, Jan. 21, 1926, pp. 112–114, 1 fig. Toledo plant manufactures amalgam; Rhode Island field prepares to produce carbonized product; charring coal dust in suspension is new venture.

COAL HANDLING

Paper Mills. Coal Handling and Boiler Operation at Northern Paper Mills, H. W. Gochnauer. Mfg. Industries (Mgmt. & Admin.), vol. 11, no. 1, Jan. 1926, pp. 23–24, 5 figs. Methods and equipment employed.

COLD STORAGE

Plants. Modern Warehouse of Terminal Refrigerating & Warehousing Co. Ice & Refrigeration, vol. 70, no. 1, Jan. 1926, pp. 118–122, 12 figs. Describes combined cold-storage and ice-making plant; details of structural features; insulation; refrigerating system, etc.

CONDUITS

Penstocks. Report on Penstock Demonstration Test, A. O. Smith. Am. Welding Soc.—Jl., vol. 5, no. 1, Jan. 1926, pp. 14–27, 18 figs. Tests made with new testing machine devised for subjecting penstocks to repeated shocks of variable intensity, as in water-hammer, and to study effect of shocks.

CORES

Oil-Sand. Oil-Sand Cores and Production, W. West. Foundry Trade Jl., vol. 33, no. 493, Jan. 28, 1926, pp. 69–73, 12 figs. Essential properties; classification of core oils; properties and character of linseed oil; changes during drying; drying process; methods of application for production; stack cores.

CORROSION

Problems. Meeting of German Corrosion Committee. Metal Industry (Lond.), vol. 28, no. 3, Jan. 15, 1926, pp. 53–55 and 66. Summarized translations of papers presented at meeting of German Official Committee for Metal Protection (Reichsausschuss für Metallschutz), as follows: Tin Plating and Lead Plating, M. Schlötter; Determination of Quality of Zinc Coatings, H. Bablik; Influence of Thermal and Mechanical Treatments upon Resistance of Aluminum to Corrosion, W. Wiederholt; Corrosion of Condenser Tubes, E. Goos; Cathodic Polarization of Metals, E. Liebreich.

COUPLINGS

Shafting and Machines, Connecting. Types of Couplings for Connecting Shafting and Machines, S. Rice. Belting, vol. 28, no. 1, Jan. 1926, pp. 29–30. Discusses flange, sleeve, clamp, compression, cut-off and flexible coupling, general construction and service to which each is adapted.

CRANES

Electric Derrick. Electric Derrick Crane. Engineering, vol. 121, no. 3136, Feb. 5, 1926, pp. 108–109, 6 figs. Crane of level-luffing type made by Anderson-Grice Co., Carnoustie, Scotland.

Full-Arch. Cranes Increase Pier Capacity over 300 Per cent. Eng. News-Rec., vol. 96, no. 3, Jan. 21,

1926, pp. 118–119, 2 figs. Full-arch cranes of 10 to 20-ton capacity built for New York Central Railroad at Weehawken, N. J., to handle boxed automobiles for export.

Jib Design. Notes on the Design of Crane Jibs, E. G. Fiegehen. Mech. World, vol. 79, no. 2037, Jan. 15, 1926, pp. 48–50, 4 figs. Detailed discussion of design.

Level-Luffing. The Toplis Level-Luffing Crane. Engineering, vol. 121, no. 3137, Feb. 12, 1926, pp. 200–202, 16 figs. partly on supp. plate. 30-cwt. crane constructed for Assoc. Portland Cement Mfrs. at their Somerset Wharf, London, for unloading cement in bags from barges and placing bags on trucks.

Locomotive. Traveling Bridge of 120 Tons (Pont roulant de 120 tonnes), M. Favre. Bul. Technique de la Suisse Romande, vol. 51, no. 26, Dec. 19, 1925, pp. 313–318, 5 figs. Details of equipment of Yverdon locomotive shop, Switzerland, including new traveling crane for handling electric locomotives; width between axes, 25 m.; operation and speeds of twin hoist, etc.

CRANKSHAFTS

Balancing. Balancing of Automobile Crankshafts (Die Auswuchtung von Automobilkurbelwellen), E. Lehr. Werkstattstechnik, vol. 19, no. 24, Dec. 15, 1925, pp. 861–865, 8 figs. Discusses increase in balancing due to increase in spin, torsional and bending vibrations, critical vibrations; describes process of balancing.

CUPOLAS

Air-Blast Conveyance to. The Conveyance of Air-Blast to Cupolas and Forced-draught Furnaces, W. J. May. Mech. World, vol. 79, no. 2036, Jan. 8, 1926, pp. 28–29, 6 figs. Discusses air propelling and distributing.

Effective Height. The Calculation of Effective Cupola Height (Die Berechung der wirksamen Kuppelofenhöhe), A. F. Hager. Zeit. für die gesamte Giessereipraxis, vol. 46, no. 50, Dec. 13, 1925, pp. 566–567, 1 fig. Describes "express" process and cupola which, with determination of blast, utilizes heat of exhaust gas for cupola melting, obtaining much higher furnace temperatures and melting speeds; process is more effective in proportion to shortness of furnace stack.

Iron-Alloy Additions. Iron Alloys as Addition in Melting Furnaces (Eisen-Legierungen als Zusatz im Schmelzofen), B. Krüder. Zeit. für die gesamte Giessereipraxis, vol. 47, no. 1, Jan. 4, 1926, pp. 2–3. Describes use of small hard, cylindrical or cubic forms of around 45-per cent iron alloy mixed with calcium cement, and known as EK packages; advantages of their use.

CUTTING METALS

Cutting Temperatures. The Measurement of Cutting Temperatures, E. G. Herbert. Am. Mach., vol. 64, nos. 7 and 8, Feb. 18 and 25, 1926, pp. 281–284 and 307–311, 28 figs.; and supplement in no. 9, Mar. 4, 1926, pp. 363–365, 6 figs.; also Engineering, vol. 121, no. 3137, Feb. 12, 1926, pp. 213–216, 13 figs. Measurement of continuous and instantaneous temperatures generated by cutting tools; galvanometer used in conjunction with tool-work thermocouple; instantaneous temperatures generated by sawing, tapping, chip shearing, chattering tools, and hardness tests; effect of high intermittent temperatures on tools. Mar. 4: Further tests indicate that free cutting range of metals is temperature effect; correlation found between Whitaker ring, work hardness and cutting temperatures. Paper presented before Instn. Mech. Engrs.

Oxygen Lance. Cutting Salamanders and Heavy Masses of Iron with an Oxygen Lance, E. E. Thum. Blast Furnace & Steel Plant, vol. 14, no. 1, Jan. 1926, pp. 18–20, 1 fig. Outlines methods whereby large masses or blocks of iron or steel may be cut to handling size; oxygen lance consists essentially of steel pipe, passing a stream of pure oxygen; operation of lance; application to drilling of salamanders, breaking up spills and ladle skulls, and cutting ingots and heavy metal masses.

CUTTING TOOLS

Lubrication and Cooling. Cutting, Grinding and Rust Prevention, J. A. Maguire. Can. Machy., vol. 35, no. 1, Jan. 7, 1926, pp. 26–27. New method of holding oil in a cutting emulsion in suspension with water, thus avoiding rust, keeping point of tool cooler, and lengthening its life.

Starting. Starting Cutting Tools, F. Horner. Can. Machy., vol. 35, no. 4, Jan. 28, 1926, pp. 13–16, 8 figs. Devices used to insure accuracy and prevent damage; special starting tools; eccentric cuts; use of loose bushings, etc.

D

DIE CASTING

Developments. Diecasting Industry Makes Progress, J. S. Gullborg. Foundry, vol. 54, no. 2, Jan. 15, 1926, pp. 48–49. Material used in early days of industry; use of stronger and more ductile material as industry grew larger; modern machines; proper filling and ventilating of dies. (Abstract.) Address before Chicago Foundrymen's Club.

DIES

Blanking. Blanking-Die Data. Am. Mach., vol. 64, no. 8, Feb. 25, 1926, p. 329, 4 figs. Reference-book sheet for laying out work for plain or progressive blanking die.

Construction of. Construction of Sheet Metal Tools, C. E. Stevens. Forging—Stamping—Heat Treating, vol. 12, no. 1, Jan. 1926, pp. 18–25, 10 figs. Details of die construction.

DIESEL ENGINES

Generator Drive. Flywheel-Type Generators for Oil Engines. Oil Engine Power, vol. 4, no. 2, Feb. 1926, pp. 76–79, 8 figs. Rotor of generator supplants flywheel, reduces generator and overall cost, saves outboard bearings.

Industrial Use. Industrial Use of the Diesel Engine, M. Rotter. Power Plant Eng., vol. 30, no. 4, Feb. 15, 1926, pp. 263–264. Consideration of Diesel installations involves efficiency, cost of fuel and lubrication, maintenance and fixed charges.

Motorship Gripsholm. Double-Acting Engines of the Motorship "Gripsholm." Power, vol. 63, no. 5, Feb. 2, 1926, pp. 166–167, 5 figs. Diesel engines are 8300 hp. each; two main engines drive two propellers directly through extended shafts and rigid couplings; each unit is made of 6 cylinders, construction details of which are given.

Submarine, in Stationary Service. Submarine Engines in Stationary Service. Power, vol. 63, no. 6, Feb. 9, 1926, p. 208, 1 fig. Use of 120-hp. 4-cylinder air-injection Diesels, formerly on navy submarines, at power plant of mine-loading station near Yorktown, Va.

Two-Stroke-Cycle. Two-Stroke Marine Diesel Engine. Engineering, vol. 121, no. 3133, Jan. 15, 1926, pp. 63–64, 13 figs. partly on supp. plate. Constructed by Mirrlees Bickerton & Day, Stockport; engine has 4 cylinders, and special feature is suction valve of rotary type driven from engine crankshaft by means of spiral gearing.

DURALUMIN

Heat Treatment. The Effect of Heat Treatment on Some Mechanical Properties and on the Microstructure of Duralumin Sheet, Rob. J. Anderson. Am. Metal Market, vol. 33, no. 12, Jan. 19, 1926, pp. 4–6 and 16. Brief abstract of results of extensive investigation on constitution, heat treatment and microstructure of duralumin, Thesis presented to Mass. Inst. Technology.

E

ELASTICITY

Limit of. Materials Testing (Ueber Materialprüfung), W. Grun. Zeit. des Vereines deutscher Ingenieure, vol. 70, no. 1, Jan. 2, 1926, pp. 9–12, 8 figs. Author maintains that there is no permanent elastic limit, but only a variable elastic limit produced by load; he recommends the plotting of a dynamic curve for permanent elongation.

ELECTRIC FURNACES

Auxiliaries. Auxiliary Equipment for Electric Furnaces, J. D. Keller. Fuels & Furnaces, vol. 4, no. 1, Jan. 1926, pp. 49–56, 17 figs. Discusses wiring diagrams, control and safety switches, relays and fuses, for resistor-type furnaces.

Brass-Melting. Melting Brass by Electricity. Elec. News, vol. 34, no. 2, Jan. 15, 1926, p. 25, 1 fig. National Bronze Co., Montreal, install 175-kva. electric furnace; excellent central-station load; one of few used for this purpose in Canada.

German Development. Electric Furnace Development in Germany, E. Blau. Fuels and Furnaces, vol. 3, no. 12, Dec. 1925, pp. 1373–1376 and 1381–1382, 2 figs. Discusses various types of furnaces, their application, capacity and power consumption, including Siemens Halske radiation furnace on Stassano model, Humbolt, A. E. G., Rodenhauser, and other types.

Hardening. Magnetic Indicator is Designed to Control Hardening Furnace Temperatures. Automotive Industries, vol. 54, no. 3, Jan. 21, 1926, pp. 104–105, 3 figs. Describes Wild-Barfield automatic hardening furnace manufactured in London, Eng.; equipment consists of electrically heated furnace and control panel electrically connected thereto; latter consists of magnetic indicator which produces musical sound until steel ceases to be magnetic, which is considered correct temperature for quenching.

Heat Balance of. Balance of Electric Furnaces (Le bilan des fours électriques), A. Levasseur. Société Française des Electriciens—Bul., vol. 5, no. 48, Aug. 1925, pp. 738–771, 13 figs. Electric, calorific and electrothermal efficiency; consumption of electrodes; induction, resistance and arc furnaces; power factors; advocates more rational study of furnaces and abandonment of mere empiricism.

Heat Balance and Efficiency of Electric Furnaces in Comparison with Other Metallurgical Melting Equipment (Wärmebilanz und Leistung des elektrischen Ofens im Vergleich mit anderen hüttenmännischen Schmelzvorrichtungen), H. Kalpers. Zeit. für die gesamte Giessereipraxis (Metall), vol. 47, nos. 1 and 3, Jan. 4 and 17, 1926, pp. 1–2 and 9–10. Gives data on heat balance and performance of cupola and blast furnace in comparison with that of electric furnace.

Heat-Treating Gears. Gears Heat Treated Electrically. Iron Age, vol. 117, no. 6, Feb. 11, 1926, pp. 401–402, 2 figs. Normalizing and hardening in automatic furnaces; compensating action of heat and large savings are features.

High-Temperature. High Frequency Electric Induction Furnaces for very High Temperatures (Fours électriques à induction à haute fréquence pour trés hautes températures), Ribaud. Jl. de Physique & Radium, vol. 6, no. 9, Sept. 1925, pp. 294–299, 5 figs. Describes two models of furnaces which may be used up to 3000 deg. cent., with linings of porous charcoal of very low heat conductivity; may be used for burning or melting refractories, and for reactions in a gaseous atmosphere, etc.; provided with optical pyrometers.

Oscillating. The Oscillating Electric Furnace, Nolly System (Four Electrique oscillant système de Nolly). Jl. du Four Electrique, vol. 34, no. 17, Dec. 1, 1925, pp. 230–232, 2 figs. Furnace used by Société Métallurgique de St.-Béron, for melting, reduction and refining, a combination of several electrodes replacing usual silica arch; cooled by circulating water; advantages, etc.

ELECTRIC LOCOMOTIVES

Crankpin Design. Crankpin Design for Electric Locomotives, J. D. Burby. Am. Mach., vol. 64, no. 7, Feb. 18, 1926, pp. 287–288, 3 figs. Discussion based on article on crankpin design in same journal, vol. 62, p. 986.

Ore Transport. Electric 1 C + C 1 Locomotives of Norwegian State Railway for Ore Transport between Riksgränsen and Narvik (Die elektrische 1 C + C 1 = Lokomotive der norwegischen Staatsbahn für die Erzförderung auf der Strecke Riksgränsen—Narvik), Reinhardt. Siemens Zeit., vol. 5, no. 11, Nov. 1925, pp. 478–483, 9 figs. Details of locomotive built by Siemen-Schuchert Works and German Gen. Elec. Co.; track gage, 1435 mm.; adhesive weight of double locomotive, 102 tons; double motors in series, 24 speeds.

Safety Device for. Safety Device for Electric Locomotives. Elecn., vol. 96, no. 2488, Jan. 22, 1926, pp. 88–89, 3 figs. New device used by Rhaetian Railways in Switzerland, developed by Brown Boveri, which operates only when locomotive is in motion, and if then only after it has covered a certain distance which can be regulated as desired; action of device commences after driver releases his hold of push button.

ELECTRIC POWER

Chicago District. Electric Power Development in Chicago District, W. S. Monroe. Power, vol. 63, no. 8, Feb. 23, 1926, pp. 294–296, 4 figs. Comprehensive review, tracing advance step by step as indicated by succeeding stations, with outline of plans for future that will provide interconnected generating capacity approximating 6,000,000 kw.

ELECTRIC RAILWAYS

Equipment. Developments in Electrical Equipment in 1925, W. D. Bearce. Ry. Rev., vol. 78, no. 1, Jan. 2, 1926, pp. 63–65, 5 figs. Railroads augment existing facilities by additions of many new cars and locomotives; oil-electric locomotives; steam-road electrification; city and suburban systems; gas-electric buses; automatic railway substations.

ELECTRIC WELDING, ARC

Applications. The Broadening Field of Arc Welding, A. G. Bissell. Machy. (N. Y.), vol. 32, no. 7, Mar. 1926, pp. 550–551, 5 figs. Application in railway field, ship construction, street-railway shops, steel mills, oil industry, airplane building, steel-tank manufacture, building construction, and mining industry.

Automatic. Welding Automatically by Electricity. Can. Mfr., vol. 46, no. 1, Jan. 1926, p. 6, 1 fig. Automatic electric welder which may be used for quantity production and for repair work; cost data.

Low-Carbon Steel. Arc Welding of Low-Carbon Steel (Wirtschaftlichkeit der Lichtbogenschweissung von Flusseisen), K. Meller. Siemens-Zeit., vol. 5, no. 11, Nov. 1925, pp. 457–464, 13 figs. Discusses economics; cost of energy for welding, labor cost of welded bars, cost of maintenance, interest and amortization; comparative cost of acetylene and electric welding, showing 50 per cent reduction in favor of electric welding.

Structural Steel. Structural Steel Welding on a Commerical Basis, H. P. Egan. Am. Welding Soc.—Jl., vol. 5, no. 1, Jan. 1926, pp. 51–58, 7 figs. Details of two-story buildings of Peerless Automobile Sales Co., Canton, Ohio, in which 95 tons of structural steel are entirely welded, both in shop fabrication and erection.

ELEVATORS

Passenger. A Notable High-Speed Elevator Installation, C. R. Callaway and E. D. Harrington. Gen. Elec. Rev., vol. 29, no. 2, Feb. 1926, pp. 84–96, 14 figs. Details of elevators in Equitable Life Assurance Society's building; variable-voltage or Ward Leonard control and its advantages; car-speed regulation; electrical and mechanical equipment, safety devices, roping, etc.

Safeguarding. The Safeguarding of Lifts, R. Lister. Engineering, vol. 121, no. 3132, Jan. 8, 1926, p. 61. Summary of chief items in elevator specification to be examined from point of view of safety.

EMPLOYEES

Explaining Plant Costs to. "Selling" Plant Costs to Employees, D. A. Hampson. Indus. Mgmt. (N. Y.), vol. 71, no. 2, Feb. 1926, pp. 77–79. How to combat idea that employers are getting rich on earnings that rightfully belong to employees; how intelligent foremen can help; how to present subject of costs to employees.

EMPLOYMENT MANAGEMENT

Analyzing Employee Attitudes. Analyzing and Rebuilding Employee Attitudes, J. F. Sherman. Indus. Mgmt. (N. Y.), vol. 71, no. 1, Jan. 1926, pp. 1915. The constructive, negative neutral types of workers; finding and winning the natural winner; points out that there is in modern industry a place for a specialized science of man engineering—analysis and measurement of attitude or motive factor, and rebuilding of it along constructive lines.

Application Forms. Concerning Application Forms, Jas. B. M. Clark. Indus. Mgmt. (N. Y.), vol. 71, no. 1, Jan. 1926, pp. 25–26. Points out disadvantages of stereotyped application forms.

ENAMELS

Weathering of Lacquer. Accelerated Weathering

as Applied to Lacquer Enamels, H. A. Nelson. Can. Chem. & Metallurgy, vol. 10, no. 1, Jan. 1926, pp. 11–13. Present state of general work on accelerated weathering; testing lacquer enamels; comparison of accelerated tests with outdoor exposure tests, and results of recent investigation on lacquer enamels carried out in laboratory of the New Jersey Zinc Co.

ENGINEERING

Science, Relation to Advancement in. The Advancement of Engineering in Relation to the Advancement of Science, A. E. Kennelly. Mech. Eng., vol. 48, no. 2, Feb. 1926, pp. 102–108, 7 figs. Definition of engineering; engineering in early times; points out that manufacture on large scale is virtually engineering itself; tendency of present engineering age toward accuracy of reasoning and precision of thought; tendency for world leadership to rest mainly upon science and its applications.

F

FACTORIES

Small. Capitalizing the Advantages of the Small Factory, D. S. Cole. Indus. Mgmt. (N. Y.), vol. 71, no. 1, Jan. 1926, pp. 27–31. Small plant in relationship to "super competition;" reducing tangible and intangible wastes.

FANS

Starting and Stopping. The Effect on the Ventilation Current of Stopping and Starting a Main Fan, R. A. H. Flugge-de Smidt. Chem., Met. & Min. Soc. of S. Africa, vol. 26, no. 5, Nov. 1925, pp. 110–114, 2 figs. Concludes that where natural ventilation assists the fan, momentum of air is killed almost instantaneously, stopping the fan; checks flow due to natural ventilation for a period; effect of starting up fan is to increase load on motor which might be obviated by starting more slowly.

FEEDWATER HEATERS

Locomotive. A Locomotive Feed-water Heater. Engineer, vol. 141, no. 3654, Jan. 8, 1926, p. 53, 2 figs. Combined feedwater heater and pump specially suited for service on locomotives, manufactured by Worthington-Simpson, of Newark-on-Trent.

FLIGHT

Path of Airplane, Determining. Photographic Time Studies of Airplane Paths, A. G. Von Baumhauer. Nat. Advisory Committee for Aeronautics—Tech. Memorandums, no. 345, Jan. 1926, 10 pp., 5 figs. Method for determining path of airplane, especially in taking off and in landing, by means of photograph camera preferably a kinetograph, which simultaneously photographs a stop watch, distance of airplane from camera and its height above ground can be determined. Translated from Dutch.

FLOW OF AIR

Measurement. The Practical Measurement of Air Flow, E. Ower. Domestic Eng. (Lond.), vol. 45, no. 11, Nov. 1925, pp. 229–231, 3 figs.; and vol. 46, no. 1, Jan. 1926, pp. 3–9, 15 figs. Discusses most suitable methods by which pressures or mechanical effects arising from motion of air may be measured; pressure-tube anemometers measuring pressures acting on a stationary body immersed in a moving fluid.

FLOW OF GASES

Pipes. Volume of Flow and Turbulence in Gas Mains (Durchgangsmenge und Turbulenz in Gasleitungen), Stoller and Stückel. Zeit. des Vereines deutscher Ingenieure, vol. 70, no. 2, Jan. 9, 1926, pp. 44–46, 5 figs. Flow of gases through pipe in which there are small plates or nozzles of 6 to 10-mm. diam.; method of measuring volume of flow; critical discussion of different methods of calculating this volume. Behavior of coke-oven gas during flow through long pipe with branches; occurrence of pressure differences up to 10 per cent due to turbulence.

FLOW OF LIQUIDS

Orifices. Experiments on Contraction of Jets of Liquids (Esperienze sulla contrazione delle vene liquide), F. de Marchi. Annali dei Lavori Pubblici, vol. 58, no. 8, Aug. 1925, pp. 689–731, 15 figs. Discusses flow of liquids through 4 orifices, 3 of which were provided with short internal tubes in addition, and studies variation in jet, develops formulas for coefficients of flow, of contraction and of velocity; effect of viscosity.

FLOW OF WATER

Measurement. Universal Measuring Tube of the Karlsruhe Hydraulic Laboratory (Universalstaurohr des Karlsruher Flussbaulaboratoriums), T. Rehbock. Zeit. des Vereines deutscher Ingenieure, vol. 70, no. 1, Jan. 2, 1926, pp. 21–24, 6 figs. Describes adjustable vacuum tube which can be arranged in three directions perpendicular to one another, and can turn on three right-angle axes in relation to one another; designed by author and carried out by F. Kneller in Karlsruhe.

FLYING BOATS

Canadian Vickers Varuna. The Canadian Vickers Varuna Flying Boat. Aviation, vol. 20, no. 3, Jan. 18, 1926, pp. 81–82, 1 fig. Seaplane designed specifically for aerial forest patrol and fire fighting.

FLYWHEELS

Stresses. The Stresses in a Fly-Wheel Due to Acceleration, A. J. S. Pippard. Instn. Mech. Engrs.—Proc., no. 1, 1926, pp. 1–12, 4 figs. Analysis of stresses due to acceleration; appendix contains note on assumption of equation.

FORGE SHOPS

Fuel-Oil System. Fuel Oil System for Forge Shop, C. C. Hermann. Machy. (N. Y.), vol. 32, no. 6, Feb. 1926, pp. 472–473, 4 figs. Requirements of fuel system; heating oil; keeping oil out of heating system; suction or intake pipe; pump requirements.

Oil-Piping System. Oil Piping System for Forge Shop, C. C. Hermann. Machy. (N. Y.), vol. 32, no. 7, Mar. 1926, pp. 568–570, 3 figs. Location of pipes; cleaning; reducing friction head; selecting pipe and fittings.

FORGING MACHINES

High-Duty. National High-Duty Forging Machine. Am. Mach., vol. 64, no. 6, Feb. 11, 1926, pp. 257–258, 4 figs. Improvements in line of forging machines of Nat. Machy. Co., Tiffin, O.

FORGINGS

Steel, Hard Spots on. Hard Spots on Steel Forgings, J. D. Gat. Blast Furnace & Steel Plant, vol. 14, no. 2, Feb. 1926, pp. 74–78, 15 figs.; also in Forging—Stamping—Heat Treating, vol. 12, no. 1, Jan. 1926, pp. 2–7, 15 figs. Summary of careful investigation of phenomena connected with these formations.

FOUNDRIES

Cost Methods. An Explanation of a Foundry Cost Method, E. T. Runge. Am. Foundrymen's Assn.—reprint, no. 498, for mtg., Oct. 6, 1925, pp. 15–21, and (discussion) 22–32. Author believes that 95 per cent of foundries have no cost system or one that is impractical; comparison of author's with other cost methods.

Describes a British System of Finding Foundry Costs, T. Smith. Foundry, vol. 54, no. 4, Feb. 15, 1926, pp. 151–153, 7 figs. Describes methods which are not hypothetical but illustrative of practice in large British iron and steel foundry.

Economics. Foundry Economics, J. Wolstenholme. Foundry Trade Jl., vol. 33, no. 493, Jan. 28, 1926, pp. 74–75. Cost of casting and part it plays in analyzing cost of engineering products; cost of molding and coremaking; piece work. (Abstract.) Paper read before Junior Instn. Engrs.

Management and Costs. Foundry Management and its Effect on Foundry Costs, Wm. J. Barrett. Am. Foundrymen's Assn.—reprint no. 498, for mtg. Oct. 6, 1925, pp. 6–14. Measuring management; comparison of iron and steel foundries; failures among foundries; measuring management in industry; successful operation through a cost system; underbidding without cost guidance; casting and cupola charging; costs as guidance in securing new equipment and as a guide in making sales.

FUELS. See COAL, LIGNITE; OIL FUEL; PULVERIZED COAL.

FURNACES, ANNEALING

Regenerative Gas-Fired. Regenerative Gas-Fired Furnaces, A. Harvey and H. W. Jackson. Metal Industry (Lond.), vol. 28, no. 1, Jan. 1, 1926, pp. 9–13, 6 figs. Equipment at new French non-ferrous works, for melting and annealing copper and brass alloys; crucible producer-gas-fired melting furnace for brass.

FURNACES, GAS

Selas. Gas Furnaces Applied to the Steel Industry, S. A. Sears. Machy. Market, nos. 1309, 1310, 1311 and 1312, Dec. 4, 11, 18 and 25, 1925, pp. 21–22, 19–20 and 22, 4 figs. Discusses theories on fuels and combustion; characteristics of gas as fuel.

FURNACES, INDUSTRIAL

Radiant-Heat. Radiant-Heat Furnaces. Engineering, vol. 121, no. 3134, Jan. 22, 1926, pp. 106–108, 7 figs. Typical examples of Krupp radiant-brick furnaces, employing principle of surface combustion, which are made for practically all industrial heating processes, such as reheating, forging, welding, annealing tempering, hardening, metal melting, etc., as well as for use in connection with manufacture of glass and pottery; any kind of clean gas can be used as fuel.

G

GAGES

Micro-Contact. Krupps Micro-Contact Gages (Kruppssche Mikrotast-Geräte), Bartholdy. Kruppsche Monatshefts, vol. 6, Nov. and Dec. 1925, pp. 218–222 and 239–241, 9 figs. New type of indicator gage for measuring drill holes, checking tolerances, and grinding work; adjustable gages of same type.

GALVANIZING

Testing Thickness of Coatings. Methods for Testing the Thickness of Zinc Coatings, H. Bablik. Metal Industry (Lond.), vol. 28, no. 2, Jan. 8, 1926, pp. 33–35, 2 figs. Author points out that increase in weight after zinc coating is no measure of amount of coating; deals with various methods for finding thickness of zinc coatings, and by means of comparative tests is able to make certain recommendations as to best methods to use, which could well form basis of standard test.

GAS ENGINES

Otto. The Use of Gas engines (Warum nicht wieder Gasmotoren?), Schäfer. Gas- u. Wasserfach, vol. 68, no. 50, Dec. 12, 1925, pp. 783–785. Otto four-stroke engine and its fifty years of existence; proposes that all liquid fuel should be reserved for engines used in locomotion, but gas should be used for stationary engines. See also comment by Elvers, pp. 785–786.

GASES

Combustion of. The Processes of Combustion as a Foundation for the Industrial Uses of Gas, F. Plenz. Gas World, vol. 84, no. 2166, Jan. 23, 1926, pp. 81–82. Concludes that for high temperature excess of either gas or air should be avoided; hydrogenous gases give highest temperatures, their use requires a good burner and gas-air mixture must be passed in at high velocities to obviate back firing. Translated from Gas- und Wasserfach.

Inert. Inert Gases, Their Technical Production and Use ("Edelgase," ihre technische Gewinnung und Verwendung), C. Rühl. Wärme- u. Kälte-Technik, vol. 27, no. 24, Dec. 15, 1925, pp. 262–264, 2 figs. Discusses neon, argon, and helium, their properties, and developments in their production; apparatus of Claude and others; Cooper-Hewitt lamps.

GEAR CUTTING

Hobbing. Accuracy and Production in Gear Hobbing, D. V. Waters. Am. Mach., vol. 64, no. 7, Feb. 18, 1926, pp. 267–270, 10 figs. Method of generating involute tooth forms by hobbing method; design features that must be incorporated in hobbing machines to produce accurate results.

GEARS

Chilled Bronze, Casting. Casting Chilled Bronze Gears. Iron Age, vol. 117, no. 9, Mar. 4, 1926, pp. 616–618, 12 figs. Developments based on research work carried on in connection with making worm-wheel blanks at plant of Buffalo Bronze Die Cast Corpn., Buffalo, N. Y.; three-sided chill is given blanks for worm gears; what process has done for strength of product.

Ground. Characteristics and Uses of Ground Gears, H. F. L. Orcutt. Instn. Mech. Engrs.—Proc., no. 5, 1925, pp. 1159–1179, 3 figs. Sets forth peculiar features of ground gear and makes suggestions for its use in engineering work for which it may be specially adapted.

Involute Internal. Involute Internal Gearing, H. Walker. Engineer, vol. 141, nos. 3658 and 3659, Feb. 5 and 12, 1926, pp. 146–149 and 172–174, 22 figs. Presents internal gearing from new point of view and expounds new method of design which largely avoids present internal-gear difficulties; comparison of internal and external gear wheels; tooth action; cutting gears; problem of trochoidal interference.

Long and Short Addendum. Advantages of Long and Short Addendum Type Railway Gearing, G. I. Kotz. Area, vol. 15, no. 1, Feb. 1926, pp. 63–67, 4 figs. Discusses advantages: increased life due to increased strength and true involute profiles, smoother operating, greater flexibility in design of motors, and ease of cutter duplication.

GOVERNORS

Steam-Turbine. Governing a Large Reheating Turbine. Power, vol. 63, no. 2, Jan. 12, 1926, pp. 54–55, 1 fig. Describes governor layout for Westinghouse machine at Crawford Avenue Station in Chicago.

GRINDING MACHINES

Centerless. Centerless Grinding Discussed, W. W. Seabury. Abrasive Industry, vol. 7, no. 1, Jan. 1926, pp. 3–5, 7 figs. Discusses work of centerless machine consisting of high-speed grinding wheel and opposed regulating wheel revolving slowly opposite the grinding wheel and forming grinding throat for material to be finished; examples of wide range of work done by this machine.

Cylinder. Positive Stone Adjustment a Feature of New Cylinder Grinder, W. L. Carver. Automotive Industries, vol. 54, no. 8, Feb. 25, 1926, pp. 360–363, 6 figs. Hutton finishing tool now used widely in production work; six abrasive stones are held rigidly in position relative to each other, but head carrying them floats relative to driving head.

H

HEAT TREATMENT

Fuel for. Selection of Fuel for the Heat-Treatment of Metal, J. A. Doyle. Machy. (N. Y.), vol. 32, no. 6, Feb. 1926, p. 503. General factors to be taken into account in selecting fuel; points out that it is more important to consider results to be obtained than fuel.

HEATING, ELECTRIC

Industrial. Status of Industrial Electric Heating. Elec. World, vol. 87, no. 4, Jan. 23, 1926, pp. 197–200, 5 figs. Rapid progress in applications to varied industries; increased production and better quality output attained in numerous installations; central stations beginning to appreciate load-building possibilities.

Panel. Electric Panel Heating, E. M. Bussy. Elec. Rev., vol. 98, no. 2510, Jan. 1, 1926, pp. 3–4, 2 figs. Discusses panel-heating system in Cinema de Paris, in London, which has 34 standard panels on auditorium ceiling, etc.; units are 6 ft. by 3 ft. by 1¼ in. fixed on surface of ceiling and finished with suitable molding following general lines of decoration.

HEATING, HOT-AIR

Gravity System. Temperature Conditions Existing, in the Rooms of a Residence Heated by a Gravity Warm Air System, V. S. Day. Am. Soc. Heat. & Vent. Engrs.—Jl., vol. 32, no. 2, Feb. 1926, pp. 73–78, 5 figs. Data and conclusions of study of temperature conditions existing in various rooms of residence of National Warm Air Heating and Ventilating Assn. at Illinois Univ.

HEATING, HOUSE

Combination Air and Water System. Combination Heating System, A. M. Daniels. Sheet Metal Worker, vol. 16, nos. 24, 25 and 26, Jan. 1, 15 and 29, 1926, pp. 866–868 and 885, 912–915 and 950–951, 7 figs. Data to enable furnaceman to design and install properly combination warm-air and hot-water heating system; location of radiators, size of pipes to serve radiators; two-pipe up-feed direct-return system; overhead down-feed system with single riser.

Fuel Savers. Tests of Household Fuel Savers and the Economical Use of Coal, F. G. Hechler. Pa. State College Eng. Experiment Station—Bul., no. 34, Oct. 1925, pp. 5–35, 10 figs. Discusses laboratory trials carried out on four fuel savers and on the furnaces alone with bituminous coal to determine their relative merits; tests do not bear out claims made for these attachments; economy of furnace with attachment was about 7 per cent better than without.

HYDRAULIC TURBINES

Coupling. Methods of Coupling Hydraulic Turbines (A propos de méthodes d'accouplement des turbines hydrauliques), R. Thomann. Bul. Technique, vol. 51, no. 24, Nov. 21, 1925, pp. 289–293, 3 figs. Discusses two turbines of 600 and 720 r.p.m., respectively, when to replace the smaller by the larger, when to couple them, how to proportion supply water for each when coupled, determining optimum of coupling, etc.

Governors. A New Hydraulic Governor. Engineer, vol. 141, no. 3659, Feb. 12, 1926, p. 191, 2 figs. Governor controls turbine by deflecting jet from wheel according to load on machine; deflector is arranged directly in front of nozzle and embraces jet instead of being above it only, as is generally the case.

High-Speed. High-Speed Turbines for the Berne Hydro-Electric Power Station. Engineering, vol. 121, no. 3133, Jan. 15, 1926, pp. 74–76, 10 figs. Details of turbines constructed by T. Bell & Co., Kriens, Switzerland, with specific speed of 970 r.p.m.; efficiency of turbines is 85 per cent as compared with 75 per cent of old Jonval turbines.

Kaplan. Kaplan and Propeller Turbines Compared, E. Englesson. Can. Engr., vol. 50, nos. 1 and 2, Jan. 5 and 12, 1926, pp. 101–105 and 121–125, 12 figs. Discusses factors governing design; compares efficiency of Kaplan, propeller and Francis turbines; operating advantages of Kaplan turbine as compared with other types; comparison between turbine and plant costs.

The Kaplan Turbine. Engineering, vol. 121, no. 3135, Jan. 29, 1926, pp. 152–154, 7 figs. Details of 10,000-hp. Kaplan turbine at Lilla Edet power station, Sweden; distinguishing characteristic of Kaplan type of propeller turbine is that vane angle is variable, runner being constructed on lines of screw propeller with feathering blades.

Racing. Racing of Turbines at Fixed and Variable Head (Note sur l'emballement des turbines sous chute fixe et sous chute variable), L. Barbillion. Electricité & Mécanique, no. 7, July–Aug. 1925, pp. 7–7 to 7–14, 6 figs. Discusses action of regulator in limiting speed, curve of speeds attained by turbines, relation between curve of angular acceleration and that of speed; comparison of speeds attained at a given moment with fixed and with variable head, etc.

Reaction. Efficiency Test on High-Head Reaction Turbine. Eng. News-Rec., vol. 96, no. 1, Jan. 7, 1926, pp. 18–19, 1 fig. Oak Grove unit on Portland system shows 90 per cent efficiency at 35,000 hp. under 882-ft. effective head.

Settings. Changing 10,000-Hp. Turbine Setting for Installing 16,000-Hp. Unit, P. F. Kruse. Power, vol. 63, no. 10, Mar. 9, 1926, pp. 358–361, 6 figs. In School Street Station of Cohoes Power & Light Corp., N. Y., setting intended for 10,000-hp. hydraulic turbine has been modified to accommodate 16,000 hp.; 3.5-per cent increase in maximum efficiency attained; large part of improvement was due to changes in design of draft tube.

HYDROELECTRIC DEVELOPMENTS

British Columbia. Development at Bonnington Falls, B. C., L. A. Campbell. Can. Engr., vol. 50, no. 3, Jan. 19, 1926, pp. 141–144, 7 figs. Details of plant of West Kootenay Power & Light Co. for total output of 60,000 hp. developed by three generating sets designed for 20,000 hp. each at 100 r.p.m. under 70-ft. head and located 50 ft. apart, center to center, generating 3-phase, 60 cycles, 7200 volts.

California. Volcanic Formations Govern Design in Pit River 3 Hydro Development, W. Dreyer. Eng. News-Rec., vol. 96, no. 4, Jan. 28, 1926, pp. 144–149, 6 figs. Dam on foundations that required grouting and energy-absorbing device; tunnel lining reinforced for full hydrostatic pressure; intake and manifold designed for least head loss.

Montana. Rocky Mountain Lake Tapped Beneath Surface in Power Development. Jl. Electricity, vol. 56, no. 2, Jan. 15, 1926, pp. 43–49, 7 figs. Development of Mystic Lake of Montana Power Co., using a natural storage basin formed by glacial action; 1000-ft. tunnel driven to lake 41 ft. beneath its surface.

Ontario. Hydro-Electric Power Commission of Ontario, Canada. Australasian Elec. Times, vol. 4, no. 9, Sept. 27, 1925, pp. 597–601, 9 figs. Compares developments of Australia with those of Ontario; trend of energy prices; Niagara, St. Lawrence and other systems.

Sweden. Electrical Progress in Sweden, G. Brockner. Elecn., vol. 96, no. 2486, Jan. 8, 1926, pp. 32–34. Discusses great advance made due to foresight and enterprise of State in exploiting state water power, state railways, in undertaking elaborate trials of railway electrification of Royal Waterfalls Board and of Royal Electrification Committee; progressing electric traction, and electric heating, etc.

West Virginia. Great Power Project on Cheat River. Mfrs.' Rec., vol. 88, no. 27, Dec. 31, 1925, pp. 66–67, 3 figs. Discusses rapid progress in construction of initial hydroelectric development of the West Penn System subsidiary, the W. Va. Power & Transmission Co., near West Virginia and Pennsylvania state line; 1000-ft. dam, 23-billion gallon reservoir.

HYDROELECTRIC PLANTS

Germany. Lake Walchen Plant and Its Turbines (Das Walchenseewerk und seine Turbinen), G. von Troeltsch. Glasers Annalen, vol. 49, nos. 11 and 12, Dec. 1 and 15, 1925, pp. 214–219 and 232–238, 18 figs. Details of reservoir head and tail water; design and operation of Francis helical turbines of 24,000 hp. and speed of 500 r.p.m., pressure regulation; impulse turbines of 18,000 hp. and 250 r.p.m.

Operation. Hydro-Electric Operating Economies, A. R. Haynes. Elec. Light & Power, vol. 4, no. 2 Feb. 1926, pp. 21–24 and 102. Features of operation as effecting water savings in governing hydroelectric station having considerable storage.

Suggestions Regarding Hydraulic Plant Operation, L. F. Harza. Power Plant Eng., vol. 30, no. 4, Feb. 15, 1926, pp. 268–270, 1 fig. Parallel operation with steam plants.

I

IMPACT TESTING

Notched-Bar Tests. An Application of the Two-Testpiece Method of Notched Bar Impact Testing, Metallurgist (Supp. to Engineer, vol. 141, no. 3657), Jan. 29, 1926, pp. 14–15. Review of work by M. Moser in Stahl u. Eisen, vol. 45, 1925, p. 1879, in which he describes applications of two-specimen method of impact testing, and gives results of analysis of large number of tests made by this method.

INDUSTRIAL MANAGEMENT

Cost Control. The Effectiveness of Costs for Controlling Waste, T. D. Nevins. Soc. Industrial Engrs.—Bul., vol. 8, no. 1, Jan. 1926, pp. 3–6. Discusses importance of costs in prevention of waste by analyzing expenses, and budgeting, and gives typical cases.

Cost Determination in Lumber Dry Kilns. Management in Lumber Dry Kilns, Thos. D. Perry. Mfg. Industries (Mgmt. & Admin.), vol. 11, no. 1, Jan. 1926, pp. 45–50, 8 figs. Useful methods for determining costs of handling and drying.

Engineer's Relation to. Relation of the Engineer to Management, H. Diemer. Professional Engr., no. 1, Jan. 1926, pp. 5–7 and 11. Discusses gradual isolation of engineer as technical specialist, industrial engineering, and its limits, management engineering, budgeting and forecasting in business analogous to designing and planning, etc.

Financial and Industrial Investigations. Scope of Financial and Industrial Investigations, A. Andersen. Mfg. Industries (Mgmt. & Admin.), vol. 11, no. 1, Jan. 1926, pp. 17–22. Conditions and sources of data; place of financial investigation; place of appraisal; differences between external and internal investigations; data from appraisal, legal, research and accounting data; use of balance sheets; relative importance of data.

Hand and Machine Labor. Hand Labor and Machinery as Producers, R. Polleys. Mfg. Industries (Mgmt. & Admin.), vol. 11, no. 1, Jan. 1926, pp. 11–12. Comparative advantages and formulas for cost calculations.

Inventory Control. The Control of Inventory Through the Scientific Determination of Lot Sizes, H. S. Owen. Indus. Mgmt. (N. Y.), vol. 71, no. 1, Jan. 1926, pp. 12–16, 5 figs. Specification or groundwork from which all control records originate.

Modern Methods. New Fields for Modern Management, W. Clark. Am. Mach., vol. 64, no. 7, Feb. 18, 1926, pp. 285–287, 1 fig. Contrast between old-fashioned and modern shops; development of sales quotas and various types of budgets; typical administrative control chart.

Production Control. An Effective Production Control System, J. J. Swan. Mfg. Industries (Mgmt. & Admin.), vol. 11, no. 1, Jan. 1926, pp. 39–43, 15 figs. Employed in manufacture of automatic printing presses.

Purchasing. Saving Money Through Scientific Purchasing, H. W. Knodel. Indus. Mgmt. (N. Y.), vol. 71, no. 2, Feb. 1926, pp. 70–77, 5 figs. System used by large corporation to place its purchasing on a sound basis.

Quantity Production. Comparing Equipment and Methods for Quantity Production, E. P. Blanchard. Machy. (N. Y.), vol. 32, no. 7, Mar. 1926, pp. 535–538, 9 figs. Methods used in studying economy of different production methods so that most efficient equipment for producing given quantities may be selected.

Simplified Procedure. Manufacturing Procedure Simplified, J. R. Bangs, Jr. Sibley Jl. of Eng., vol. 40, no. 1, Jan. 1926, pp. 2–6 and 7 (adv. sect.), 3 figs. Discusses fundamentals of manufacturing procedure and principles of simplified method based on Taylor, for office functions and shop functions, movement of orders and instructions from office to shop and returns from shop to office, etc.

Small Factories. Capitalizing the Advantages of the Small Factory, D. S. Cole. Indus. Mgmt. (N. Y.), vol. 71, no. 2, Feb. 1926, pp. 106–111, 4 figs. Points out disadvantages of "complete line" manufacturing for small shop.

Standard Practice Instructions. Standard Practice Instructions, P. M. Atkins. Am. Mach., vol. 64, no. 1, Jan. 7, 1926, pp. 23–27, 5 figs. Necessity for handling on explicit instructions for routine work; example worked out for details handled by balance of stores clerk.

INDUSTRIAL MOBILIZATION

Bridgeport Ordnance District, Work of. Mobilization Plans of the Bridgeport Ordance District, B. A. Franklin. Am. Mach., vol. 64, no. 6, Feb. 11, 1926, pp. 223–228, 1 fig. Practical application of general plan of industrial mobilization; account of what Bridgeport Ordnance District has accomplished.

INDUSTRIAL ORGANIZATION

Personnel, Choice of. Judging Organization and Personnel, A. Andersen. Mfg. Industries, vol. 11, no. 2, Feb. 1926, pp. 113–117. Broad and detailed tests on organization; organization balance; relations of organization and personnel; functions of committees; personal statistics; personnel qualifications and analysis; vital importance of personnel.

INDUSTRIAL PLANTS

Atwater Kent, Philadelphia. The Modern Manufacturing Plant, H. Ashworth. Mfg. Industries (Mgmt. & Admin.), vol. 11, no. 1, Jan. 1926, pp. 7–10, 3 figs. Atwater Kent Co. has world's largest radio factory; single-story building with 15 acres under glass; summary of data.

Safety Promotion. Relation of Safety and Production, Rob. H. Luckenbach. Mfg. Industries (Mgmt. & Admin.), vol. 11, no. 1, Jan. 1926, pp. 25–28, 6 figs. Writer endeavors to emphasize important points which have assisted in improving safety of plant of E. G. Budd Mfg. Co.

Scientific Planning. Scientific Planning for the New Western Electric Plant, O. C. Spurling. Mfg. Industries, vol. 11, no. 2, Feb. 1926 pp. 102–106, 8 figs. Selection of site for new plant; plans for ultimate development of Kearny Works in New Jersey; construction of multi-story buildings; coal and ash-handling building; summary of data on plant.

INDUSTRIAL TRUCKS

Electric. Electric Trucks in the Locomotive Repair Shop, H. J. Payne. Ry. Elec. Engr., vol. 17, no. 1, Jan. 1926, pp. 21–23, 7 figs. Practice of one railroad indicates that this equipment fills definite need; work done by elevating platform trucks; saving on chip removal.

Foundries. Trucks Handle Materials in the Foundry, C. C. Hermann. Iron Trade Rev., vol. 78, no. 7 Feb. 18, 1926, pp. 455–456, 8 figs. Describes trucks designed by author and in service at plant of Union Malleable Iron Co., Moline, Ill.

Storage-Battery. Trucks Reduce Material Handling Costs in Automotive Plants, H. J. Payne. Automotive Industries, vol. 54, no. 3, Jan. 21, 1926, pp. 100–102, 5 figs. Application of storage-battery equipment to shop hauling yields high returns.

INSULATION, HEAT

Buildings. Advantages of Heat Insulation in Hotels, Apartment Houses, and Private Residences, R. H. Heilman. Am. Soc. Heat. & Vent. Engrs.—Jl., vol. 32, no. 1, Jan. 1926, pp. 37–52, 12 figs. Discusses various types of insulating materials and gives data helpful to heating engineer in selecting and directing use of suitable heat insulation.

INTERNAL-COMBUSTION ENGINES

British Show, Olympia. The Shipping, Engineering and Machinery Exhibition. Automobile Engr., vol. 16, no. 211, Jan. 1926, pp. 2–11, 28 figs. Notes on exhibits in internal-combustion-engine section.

Fuel Atomizers. Benkert Process of Atomizing (Das Benkert-Verfahren zur Zerstäubung von Brennstoffen, insbesondere Schweröilen in kompressorlosen Verbrennungskraftmaschinen), J. Eggers. Schiffbau, vol. 26, no. 24, Dec. 23, 1925, pp. 799–803, 9 figs. Design and operation of atomizer specially used for heavy oils in compressorless internal-combustion engines.

Fuels. Fuels for High-Compression Engines, S. W. Sparrow. Oil & Gas Jl., vol. 24, no. 34, Jan. 14, 1926, pp. 118–122 and 184–190, 13 figs. Discusses characteristics with reference to preignition and detonation; compression ratio and preignition; methods of measuring detonation, etc.

Piston Temperatures. Piston Temperatures and Heat Flow in High-Speed Petrol Engines, A. H. Gibson. Engineering, vol. 121, nos. 3135 and 3136, Jan. 29 and Feb. 5, 1926, pp. 150–152 and 183–185, 3 figs. Results of measurement of piston temperatures made by author during past 7 years. (Abridged.) Paper read before Instn. Mech. Engrs.

Steam Cooling. Evaporative Cooling, H. C. Harrison. Soc. Automotive Engrs.—Jl., vol. 18, no. 2, Feb. 1926, pp. 195–200, 5 figs. Describes results of 7 years' experimentation with various modifications of original system and declares that evaporative or steam cooling has proved itself to be most satisfactory; shortcomings of water-cooled system; experiments with numerous variations of original system of evaporative cooling; enumerates general principles said to apply to successful operation. Author suggests use of term evaporative cooling instead of steam cooling, because of latter's association with steam heating.

Supercharging. Supercharging Internal-Combustion Engines, C. R. Short. Soc. Automotive Engrs.—Jl., vol. 18, no. 2, Feb. 1926, pp. 185–194, 23 figs. Historical data concerning engines in which supercharging principle has been employed, such engines being those which utilize special means whereby cylinder charger is increased beyond normal charge obtained by filling cylinder at atmospheric pressure; outlines supercharging methods, including forced and supplemented induction, scavenging and use of 2-stroke cycle; suggests possibility of designing supercharger that will produce greater torque at low speed and enumerates advantages that would result for passenger-car engines.

[See also AIRPLANE ENGINES; AUTOMOBILE ENGINES; DIESEL ENGINES; GAS ENGINES; OIL ENGINES.]

IRON

Constitution. The Constitution of Iron (Ueber die Konstitution des Eisens), F. Wever. Physikalische Zeit., vol. 26, no. 20, Nov. 16, 1925, pp. 698–699. Summary of present knowledge of allotropy of iron; identity of alpha and delta modifications of iron, first indicated by X-ray analysis, is confirmed by study of binary systems, iron-silicon and iron-tin; solubility of carbon in gamma iron is regarded as due to carbon atoms filling up gaps in face-centered lattice.

Corrosion. The Nature of the Protective Film of Iron, T. Fujihara. Am. Electrochem. Soc.—advance paper, no. 1, for mtg. Apr. 22–24, 1926, pp. 1–8, 9 figs. Discusses phenomena connected with formation of protective film or membranes when drops of water are placed on a polished iron surface.

Protective Coatings. Note on the Protection of Iron by Cadmium, H. S. Rawdon. Am. Electrochem. Soc.—advance paper, no. 3, for mtg. Apr. 22–24, 1926, pp. 21–30, 3 figs. Results of qualitative experiments with specimens of steel and iron, in each of which a plug of another metal was inserted and immersed in dilute sodium-chloride solution; zinc and cadmium behaved alike in preventing corrosive attacks of iron.

IRON AND STEEL

Bibliography. Review of Iron and Steel Literature for 1925, E. H. McClelland. Blast Furnace & Steel Plant, vol. 14, no. 1, Jan. 1926, pp. 49–51, also Forging—Stamping—Heat Treating, vol. 12, no. 1, Jan. 1926, pp. 15–17. Classified list of more important books, serials and trade publications during year, with few of earlier date, not previously announced.

IRON CASTINGS

Cleaning. Cleaning Gray Iron Castings, E. H. Trick. Foundry, vol. 54, no. 2, Jan. 15, 1926, pp. 71–72, 4 figs. Methods and machinery used to handle castings from shakeout to warehouse in Southwestern plant making varied work.

Flywheels. Making a 60-Ton Fly Wheel. Foundry Trade Jl., vol. 33, no. 492, Jan. 21, 1926, pp. 49–50, 1 fig. Wheel was made in 6 sections with strong sand cores only; 8 core boxes made all the 80 cores for rim; describes method adopted.

Light. The Production of Light Grey-Iron Castings, D. McQueen. Foundry Trade Jl., vol. 33, no. 492, Jan. 21, 1926, pp. 53–54. Main considerations in iron for light castings are that it should be fluid so as to run thin castings and also soft, as large percentage of castings have to be drilled and some polished; influence of manganese and carbon; sulphur in light castings; mis-run castings; sands for light work; molding methods. (Abstracts.)

Road Rollers. Making a Motor Road Roller, B. Hird. Foundry Trade Jl., vol. 32, no. 488, Dec. 24, 1925, pp. 527–529, 12 figs. Methods and equipment employed in making casting for hind roller of a Barford Perkins motor road roller; these castings weigh from 3 to 6 tons; molding in box for bottom part; coremaking.

J

JIGS

Automobile Production. Jigs and Special-Purpose Machines. Automobile Engr., vol. 16, no. 211, Jan. 1926, pp. 32–35, 7 figs. Principles of design as applied to British automobile production.

Center Drilling. Universal Center Drilling Jig, H. Simon. Machy. (N. Y.), vol. 32, no. 6, Feb. 1926, 450–453, 6 figs. Important features of design; methods of locating and holding work; points on building jig; drilling holes of center.

V-Block Designs for. V-Block Designs for Jigs and Fixtures. Am. Mach., vol. 64, no. 4, Jan. 28, 1926, p. 171. Reference-book sheet.

L

LACQUERS

Tests. Durability of a Colored Lacquer Containing Various Resins, H. A. Gardner. Paint Manufacturers' Assn. of U. S., Sci. Section—Circular, no. 252 Oct. 1925, pp. 168–173, 2 figs. Details of tests to determine effect of various resins; durability of brush lacquer, with results tabulated.

Physical Tests on Lacquers, H. A. Gardner and H. C. Parks. Paint Manufacturers' Assn. of U. S., Sci. Section—Circular, no. 253, Nov. 1925, pp. 174–194, 4 figs. Tests to determine physical properties, including tensile strength and elongation of films, roof-exposure tests; cold-water test, baking, bending, etc., together with composition of lacquer.

LATHES

Tailstocks. Design of Lathe Tailstocks, F. Horner. Machy. (N. Y.), vol. 32, nos. 5, 6 and 7, Jan., Feb. and Mar. 1925, pp. 393–397, 11 figs.; 474–477, 11 figs.; and 580–583, 10 figs. Typical designs for different classes of machines. Jan.: Simple types of tailstocks, spindle clamping methods and other clamping devices for tailstock spindles. Feb.: Wedge type of clamp for tailstock spindle; tailstock of heavy design and for special lathes. Mar.: Automatic tailstocks; tailstocks of special design.

LIGHTING

Factories. Illumination and Industrial Welfare, A. F. McBride. Illum. Eng. Soc.—Trans., vol. 21, no. 1, Jan. 1926, pp. 61–69. Regulations affecting welfare of industrial workers with particular emphasis on importance of adequate industrial illumination and its relation to efficient production, improved safety conditions, better eyesight and health.

Illumination of General Electric Factories, Office and Warehouses. Illum. Eng. Soc.—Trans., vol. 21, no. 1, Jan. 1926, pp. 11–24, 19 figs. Discusses practice employed by General Electric Co. with regard to illuminating its factories, offices, warehouses, including methods of procedure of a committee whose function it is to investigate and design illumination for these areas; progress and results of undertaking and provisions for the future.

LIGNITE

Briquetting. Briquetting of Lignite (Beiträge zur Klärung der Brikettierung der Braunkohle), F. W. Foos. Braunkohle, vol. 24, no. 34, Nov. 21, 1925, pp. 753–756, 2 figs. Discusses extent to which briquets may be heated by compression in the press; cooling.

Drying. Numerical Determination of the Various Magnitudes in Drying, with Special Reference to Lignite (Zahlenmässige Bestimmung der verschiedenen Grössen bei der Auftrocknung, unter besonderer Berücksichtigung der Braunkohle), K. Deimler. Braunkohle, vol. 24, no. 39, Dec. 26, 1925, pp. 853–860, 6 figs. Determination of values reached at various stages of drying and changes taking place, by linear equations; application to briquetting plants and to solution of practical problems.

Spiral Turning Baffles in Tube Dryers for Lignite Briquet Plants (Spiralwendeleisten in Röhrentrocknern von Braunkohlen-Brikettfabriken), E. Böer. Braunkohle, vol. 24, no. 34, Nov. 21, 1925, pp. 756–760, 5 figs. Discusses steam circulation in drum-dryers; turning of drum; insertion of spiral baffles; types developed by Zeitz, Buckau, resulting in greater drying efficiency.

LOCOMOTIVE BOILERS

Feedwater Treatment. Water Treatment and Locomotive Boiler Washing, C. C. Bailey. Baldwin Locomotives, vol. 4, no. 3, Jan. 1926, pp. 40–51, 24 figs. Various types of installations and their operations.

Repair Shop. Boiler Shop Methods and Equipment at Juniata. Boiler Maker, vol. 26, no. 2, Feb. 1926, pp. 35–38, 12 figs. Discusses layout of P.R.R. boiler shop near Altoona, Pa.; plant and equipment; fabricating boiler sheets, light and heavy flanging operations, etc.

LOCOMOTIVES

Classification. Kind, Species, Type, Class (Art, Gattung, Type, Klasse), E. H. Metzeltin. Hanomag, vol. 12, no. 146, Dec. 1925, pp. 194–197. New classification adopted by German government for steam locomotives; explains difference in designation from that of various federal states.

Design. Present Tendencies in Locomotive Construction (Les Tendances actuelles dans la Construction des Locomotives), M. F. Legein. Assn. des Ingénieurs de l'Ecole Polytechnique de Bruxelles—Bul. Technique, vol. 21, no. 1, 1925, pp. 16–32, 5 figs. Developments since 1900; superheating and its success; Glehn saturated steam types; position of cylinders; 3-cylinder types and their advantages; increased boiler efficiency, feedwater heating; turbine locomotives.

Diesel-Engined. Clutch Drive Locomotive of 1600 HP. Oil Engine Power, vol. 4, no. 2, Feb. 1926, pp. 82–93, 2 figs. Direct-drive Diesel locomotive now being built at Krupps to specifications of American railroad; drawbar pull 40,000 lbs., high speed 49.75 m.p.h.; mechanical transmission throughout, avoiding electric or hydraulic intermediary stysems.

4-8-2. Examples of Recent Locomotives of the 4-8-2 Type. Ry. Mech. Engr., vol. 100, no. 1, Jan. 1926, p. 21. Tabular data, arranged in order of weight.

4-8-2 Type Locomotives for N. Y. C. Ry. Age, vol. 80, no. 5, Jan. 30, 1926, pp. 329–331, 4 figs. Designed for handling heavy trains over Mohawk division between Albany and Syracuse.

Testing. Methods Employed by the Italian State Railways for Testing Locomotive Performances, A. Mascini and G. Corbellini. Int. Ry. Congress Assn.—Bul., vol. 7, no. 13, Dec. 1925, pp. 2523–2525. Discusses dynamometer car and its equipment, methods of carrying out running tests on steam locomotives, determination of steam and coal consumed in heating test trains, information taken from indicator cards. Translated from Rivista Tecnica della Ferrovie Italiane.

Texas-Type. Texas & Pacific 2-10-4 Locomotives. Ry. Mech. Engr., vol. 100, no. 1, Jan. 1926, pp. 5–12, 17 figs. Engines, known as Texas type, have 4-wheel articulated trailer; tractive force with booster, 96,000 lb.; built by Lima Locomotive Works. See also Boiler Maker, vol. 26, no. 1, Jan. 1926, pp. 5–7, 7 figs.

Three-Cylinder. Eighty Years of Three-Cylinder History, W. A. Autin. Baldwin Locomotives, vol. 4, no. 3, Jan. 1926, pp. 27–39, 20 figs. Three-cylinder construction and experiments in England and United States, Germany and other countries.

Three Cylinder Locomotive Performance, F. E. Russell. Ry. Rev., vol. 78, no. 1, Jan. 2, 1926, pp. 34–40, 14 figs. Southern Pacific 4-10-2-type engines handle heavier trains in mountainous territory. See also Ry. & Locomotive Eng., vol. 39, no. 1, Jan. 1926, pp. 1–5, 6 figs.

Types. General Notes on Locomotives (Considérations générales sur les locomotives), E. Vétillard. Arts et Métiers, vol. 78, no. 61, Oct. 1925, pp. 393–401, 12 figs. Discusses various types from Atlantic to Decapod; calculation of tractive effort and power, adhesion, resistance, speed limits, brakes,etc.

Three New Locomotive Types in '25, C. B. Peck. Ry. Age, vol. 80, no. 1, Jan. 2, 1926, pp. 47–49, 3 figs. All demonstrate that capacity possibilities of single-unit driving wheelbases have not been exhausted; 2-8-4 type built by Lima Locomotive Works; 4-10-2, three-cylinder, built for Southern Pacific; and 2-10-4 type, for Texas & Pacific, built by Lima Locomotive Works.

LUBRICATION

Cutting Tools. Importance of Lubrication in Working of Metals (Importance de la lubrication, dans le travail d'usinage des métaux), J. Jacquet. Arts et Métiers, vol. 78, no. 61, Oct. 1925, pp. 407–411, 3 figs. Use of cutting compounds for increasing speed of cutting and experiments carried out.

Journal. A Graphical Study of Journal Lubrication, H. A. S. Howarth. Mech. Eng., vol. 48, no. 2, Feb. 1926, pp. 131–132 and (discussion) 132–133, 3 figs. Continues investigation of journal lubrication reported to Society under same title in 1923 and 1924; presents friction curves for central and offset partial bearings whose curvature radius exceeds that of journal; characteristics of fitted partial bearings are studied, including their varrying capacities and friction.

LUMBER

Handling. Reducing Lumber Handling Costs, Mfg. Industries, vol. 11, no. 2, Feb. 1926, pp. 111–112, 6 figs. Straight-line production methods in new planing mill of Southern Pac. R.R.

M

MACHINE SHOPS

Cost Determining. Determining Shop Costs, J. A. Thomas. Machy. (N. Y.), vol. 32, no. 7, Mar. 1926, pp. 533–534. Relation of cost system to charge for work; practicable methods of ascertaining cost of job.

MACHINE TOOLS

Railway Purchases, 1925. The Year's Purchases of Machine Tools, L. R. Gurley. Ry. Mech. Engr., vol. 100, no. 1, Jan. 1926, pp. 42–55. Lists from 88 roads show practically same number of units bought in 1925 as in 1924; comparison of types purchased; materials-handling equipment. See also Ry. Age, vol. 80, no. 1, Jan. 2, 1926, pp. 105–108.

Used. The Problem of Used Machine Tools. Machy. (N. Y.), vol. 32, no. 7, Mar. 1926, pp. 543–544. Advantages of a used machinery department, and how to operate such a department; organizing sales of used machines.

MACHINING METHODS

Automobile Cylinder Heads. Willys-Knight Production Methods, F. H. Colvin. Am. Mach., vol. 64, no. 5, Feb. 4, 1926, pp. 191–194, 9 figs. Individual heads that carry special packing rings over which inner sleeve passes; how wide multi-ground rings are made.

MALLEABLE CASTINGS

Annealing. Malleable Iron (La Malléable), M. Guedras. Fonderie Moderne, vol. 20, Jan. 1926, pp. 4–6. Discusses oxidizing cementation known as annealing, its chemical and thermal aspects; use of Ardennais furnace in France; formation of skin due to oxidation.

MATERIALS HANDLING

Products Handling. Handling Products in the Squibb Plant, Geo. E. Hagemann. Mfg. Industries (Mgmt. & Admin.), vol. 11, no. 1, Jan. 1926, pp. 35–38, 7 figs. Conveyors, elevators, lift trucks, spiral chutes and gravity methods used in effective combination.

METAL DRAWING

Shells, Irregularly Shaped. The Drawing of Irregularly Shaped Hollow Bodies (Das Ziehen unregelmässig geformter Hohlkörper), H. D. Brasch. Zeit. des Vereines deutscher Ingenieure, vol. 70, no. 2, Jan. 9, 1926, pp. 53–55, 33 figs. Investigation of conditions which influence drawing process in production of irregular shapes, such as those with cylindrical cross-section but profiled longitudinal section, or with rectangular or irregular cross section; rules to be observed are, proper selection of form, accurate production of tool, good drawing capacity of material, proper drawing speed, good lubrication, and proper adjustment.

METALS

Drawing Properties. Some Attempts to Measure the Drawing Properties of Metals, Wm. S. Montgomery, Jr., and E. R. Enders, Jr. Mech. Eng., vol. 48, no. 2, Feb. 1926, pp. 119–124, 2 figs. Results of series of tests made with idea of ascertaining whether or not measurable properties bear any relation to drawing properties of metals.

Finishing. Modern Metal Finishes, W. J. Muskella. Sibley Jl. Eng., vol. 39, no. 9, Dec. 1925, pp. 423–425 and 428, 1 fig. Discusses lacquering, oriental and nitrocellulose, or pyroxylin lacquer; porcelain enameling using a glass-like substance fused at red heat at about 1800 deg. fahr.; japanning material on metal articles which are baked in an oven at about 250 deg. fahr.

Grain Growth. On the Restraint of Exaggerated Grain Growth in Critically Strained Metal, G. L. Kelley and J. Winlock. Franklin Inst.—Jl., vol. 201, no. 1, Jan. 1926, pp. 71–78. Exaggerated grain growth and how to avoid it; concludes that it may often be restrained or even prevented by preliminary heating for more or less lengthy period at temperatures below that at which grain growth would normally occur.

High Temperatures, Resistance to. The Use of

Metals at High Temperatures, W. Rosenhain. Metallurgist (Supp. to Engineer, vol. 141, no. 3657), Jan. 29, 1926, pp. 2–4, 2 figs. Discusses manner in which materials are exposed to high temperatures and mechanism of their resistance under these adverse conditions.

Recrystallization. Contribution to the Knowledge of Recrystallization (Beitrag zur Kenntnis der Rekristallisation), H. Hanemann. Zeit. für Metallkunde, vol. 18, no. 1, Jan. 1926, pp. 16–17, 2 figs. Relation between impact and grain size; slip surfaces as seat of strain hardness, recrystallization and latent work.

Recrystallisation. Metallurgist (Supp. to Engineer, vol. 141, no. 3657), Jan. 29, 1926, pp. 13–14, 2 figs. Review of work by H. Hanemann in Zeit. für Metallkunde, Oct. 1925, showing that threshhold value of deformation required to cause recrystallization increases rapidly with falling temperature, until at sufficiently low temperature recrystallization is not brought about by any degree of deformation.

Single Crystals. Certain Physical Properties of Single Crystals of Tungsten, Antimony, Bismuth, Tellurium, Cadmium, Zinc, and Tin, P. W. Bridgman. Am. Soc. Arts & Sci.—Proc., vol. 60, no. 6, Oct. 1925, pp. 305–383, 10 figs. Discusses method of growing large single crystals, measurements and computation of thermal expansion, electrical resistance, elastic constants, etc.; experimental methods of measuring strain; magnetic properties; gives table of principal results, linear compressibilities, etc.

Strength. The Effect of Tension on the Transverse and Longitudinal Resistance of Metals, P. W. Bridgman. Am. Soc. Arts & Sci.—Proc., vol. 60, no. 8, Oct. 1925, pp. 423–449, 1 fig. New experimental method for measuring change of resistance in a metal under tension with direction of flow at right angles to tension; results of measurement on aluminum, gold, copper, silver, platinum, iron, nickel, etc.

Structure. Minute Structure of Metals (La Nature intime des Metaux), E. Trasenster. Fonderie Moderne, vol. 19, Dec. 1925, pp. 272–275. Discusses crystalline nature of grains, single-crystal test pieces, results of spectroscopic analysis, nature of joints or bonds of grains, microstructure of alloys.

Thin Transparent Films of. Thin Transparent Films of Metal. Metallurgist (Supp. to Engineer, vol. 141, no. 3657), Jan. 29, 1926, p. 6. Describes process worked out by C. Müller at the Reichsanstalt at Charlottenburg, who has succeeded in making excessively thin films of nickel, copper, etc., which are continuous and sufficiently strong to be reasonably handled; they can even be soldered or welded together to form thermocouples; they are also transparent.

MILLING MACHINES

Repairing. Repairing Milling Machines, J. H. Smit. Machy. (N. Y.), vol. 32, no. 7, Mar. 1926, pp. 552–553. Determining errors in slides; making corrections.

MOLDING METHODS

Loam. Loam Molding Methods. Foundry, vol. 54, nos. 2, 3 and 4, Jan. 15, Feb. 1 and 15, 1926, pp. 55–58, 112–115 and 137–141, 24 figs. Jan. 15: Points out that it may be advantageous to build temporary loam pattern for use either with a loam or dry sand mold. Feb. 1: Discusses method usually referred to as thicknessing; advantages of sweeping a thickness; methods of application. Feb. 15: Manner in which straw rope is applied to core barrels and purpose it serves in casting.

Water Wheels. Waterwheels Aid in Power Plant Advance, P. Dwyer. Foundry, vol. 54, nos. 1 and 2, Jan. 1 and 15, 1926, pp. 2–6 and 45–48, 16 figs. Molding practice followed in making waterwheels, at foundry of Jas. Leffel & Co., Springfield, O.; steel buckets; mold for small wheel. Jan. 15: Foundry methods employed in making small waterwheels.

MOTOR BUSES

Bristol. The Latest Bristol Production. Motor Transport (Lond.), vol. 42, no. 1091, Jan. 25, 1926, pp. 115–117, 7 figs. Latest model by Bristol Tramways & Carriage Co. for single-deck bodies with 32 seats; 4-cylinder mono-block engine with detachable head; wheelbase, 16 ft.; overall length, 25 ft. 6 in.

MOTOR TRUCKS

Chassis Suspension. Chassis Suspension for Industrial Vehicles. Motor Transport (Lond.), vol. 42, no. 1092, Feb. 1, 1926, pp. 129–131, 6 figs. Recent improvements in design; effect of imperfect suspension; suiting the spring to its load, spring lubrication, etc.

GMC Heavy-Duty. GMC Heavy-Duty Trucks Redesigned; Prices are Increased, L. S. Gillette. Automotive Industries, vol. 54, no. 6, Feb. 11, 1926, pp. 221–222, 1 fig. Fisher-built steel cab among features of new "Big Brute" line; frontal design changed; stroke of engine on 3½ and 5-ton models increased; cylinder head in two pieces; crankshaft is heavier.

Krupp. Krupp Motor Trucks in Modern Transportation (Krupp-Lastkraftwagen im neuzeitlichen Wirtschaftsverkehr), Sachtleben. Kruppsche Monatshefte, vol. 6, Nov. 1925, pp. 209–218, 19 figs. Trucks and trailers or dump cars for transporting various kinds of materials; tanks for oil or water, street-cleaning and fire-department vehicles; omnibuses.

Producer-Gas. The Franco-Belgian Trials of Producer Gas Lorries, R. E. Mathot. Gas & Oil Power, vol. 21, no. 244, Jan. 7, 1926, pp. 75–76. Details of laboratory tests at Automobile Club of France of Panhard-Levassor engine, fitted with its producer on a bench directly coupled to dynamo acting as dynamometric brake, also Belgian Etia producer.

Use of Producer Gas for Automobiles (L'Application du Gaz pauvre à la Traction automobile), E. Warnant. Assn. des Ingénieurs de L'École Polytechnique de Bruxelles—Bul. Technique, vol. 20, no. 4, 1924, pp. 141–150, 1 fig. Discusses design of suitable gas producer, and adaptation of engine to this fuel so as to secure running and load capacity comparable to gasoline trucks.

Trailers. Trailers for Automobiles (La remorque Automobile), Chevalier. Arts et Métiers, vol. 78, no. 61, Oct. 1925, pp. 412–422, 21 figs. Design and construction of two-wheeler and four-wheeler, for motor trucks at variable adhesion and with adjustable adhesion; special trailer design.

Welding Bodies. Truck Bodies Built by Welding Stronger, Cost Less, R. E. Kinkead. Automotive Manufacturer, vol. 67, no. 10, Jan. 1926, pp. 5–8, 4 figs. Results of tests show that the electrically welded truck provides 100 per cent joints as against maximum of 75 per cent for riveted product; doubles useful life of the body and affords one-third reduction in production costs, is simple and easy to design, etc.

O

OIL ENGINES

Cold-Starting. Blackstone Spring-Injection Cold Starting Engine. Elec. Times, vol. 69, no. 1786, Jan. 7, 1926, pp. 12–13, 2 figs. Details of improved oil prime mover developed by Blackstone & Co. of Stamford, in which air compressor and hot-bulb attachment of cylinder head is replaced by mechanical injection device together with completely water-cooled cylinder head; injection device having a low-pressure fuel-measuring pump, high-pressure fuel-injection pump and spring-loaded fuel-injection valve, etc.

15,000-B.Hp. A Large Double-Acting Oil Engine. Engineer, vol. 141, no. 3657, Jan. 29, 1926, p. 134. Details and tests of 9-cylinder, double-acting 2-cycle 15,000-b.hp. oil engine built under license form M.A.N. Co., Ausgburg; claimed to be largest unit yet constructed; it will be employed for driving 10,000-kw. alternator at Neuhof Electricity Works, Hamburg.

Fuel Injection. Pumpless Fuel Injection for New Engine. Oil Engine Power, vol. 4, no. 1, Jan. 1926, pp. 15–19, 8 figs. Discusses Cummins system and fuel system of high-speed light-weight design.

Heavy-Oil. The Attendu Heavy-Oil Engine, A. C. Attendu. Soc. Automotive Engrs.—Jl., vol. 18, no. 2, Feb. 1926, pp. 214–221, 8 figs. Requirements to be met; details of aviation engine built for U. S. Navy; and results of tests; it is 2-cylinder engine having bore of 5½ in. and stroke of 6½ in., designed to develop 100 b.hp. at 1500 r.p.m.; possible applications of this type of engine include trucks, motor buses, railway motor cars, airships, tractors, pleasure craft and tug, with low cost of power production that could not be dreamed of with gasoline engine.

McIntosh. High Efficiency Claimed for New Two-Stroke Engine. Automotive Industries, vol. 54, no. 3, Jan. 21, 1926, p. 102, 1 fig. Exceptional efficiency is claimed for engine developed by J. McIntosh Engine Co., Cleveland, O., for marine purposes.

Mirrlees. A 600 B.H.P. Oil Engine Generator Set-Engineer, vol. 141, no. 3568, Feb. 5, 1926, p. 158, 2 figs. New type of engine, made by Mirrlees, Bickerton & Day, which is designed for output of 100 b.hp. per cylinder at moderate speed of 250 r.p.m.; 6-cylinder engine of this type has been installed at electricity works of Basingstoke Corpn., coupled to 410-kw. d.c. generator.

Recooling Jacket Water. Recooling Oil-Engine Jacket Water, E. J. Kates. Power, vol. 63, no. 2, Jan. 12, 1926, p. 57, 1 fig. How cooling towers are made; defect of open cooling system is rapid concentration of mineral salts through evaporation.

OIL FUEL

Burners for. Burning of Fuel Oil, E. T. Keenan. Southern Power Jl., vol. 44, no. 1, Jan. 1926, pp. 36–38, 4 figs. Discusses analysis of liquid fuels; how fuel oil is burned, methods of atomizing, selection of type of burner, etc.

Synthetic. Synthetic Fuels (Synthetische Kraftstoffe), W. Ostwald. Motorwagen, vol. 28, no. 26, Sept. 20, 1925, pp. 565–567. Discusses quality calories and heat calories and transformation of latter into former; reduction of raw material into elements for synthesizing of fuels, or direct synthesis from given material; Bergins and Badische processes.

Testing. Modern Test Methods for Fuel Oil, W. D. Campbell. Nat. Engr., vol. 30, no. 2, Feb. 1926, pp. 57–60, 1 fig. Instructions for handling bomb calorimeter in making tests and precautions to be taken to insure accuracy, how to determine acid and sulphur content, how to calculate results.

OXYACETYLENE WELDING

Aluminum. Autogeneous Welding of Aluminum and Its Alloys, A. Eyles. Am. Mach., vol. 64, nos. 7 and 9, Feb. 18, Mar. 4, 1926, pp. 275–279 and 353–356, 22 figs. Feb. 18: Difficulties to be contended with; pure gases necessary; welding rods for sheets and castings; preparing joints; goggles and color of glass. Mar. 4: Welding aluminum-alloy castings; factors governing torch selection; regulation of flame; after treatment of welded joints.

Frama Process. The Frama Process and Its Devices (Das Frama Verfahren mit seinen Vorrichtungen), L. Thoma. Autogene Metallbearbeitung, vol. 18, nos. 20, 21, 23 and 24, Oct. 15, Nov. 1, Dec. 1 and 15, 1925, pp. 302–305, 320–323, 351–354 and 359–365, 13 figs. Theory and practice of oxyacetylene flame and injector burner and pressure regulation; Frama welding burner in which quantities of the two gases are regulated in predetermined ratio in accordance with strength of flame; Frama valve and its uses for acetylene in flasks and acetylene generators; Frama motor compressor for raising acetylene to excess pressure for Frama burner.

Hose Connection for Equipment. Standard Hose Connections for Welding Equipment. Am. Mach., vol. 64, no. 6, Feb. 11, 1925, p. 253. Reference-book sheet for holding and fastening devices.

P

PAINTING

Spray. Recent Developments in Spray Painting, H. A. Gardner. Paint Mfrs.' Assn. of U. S.—Sci. Section, no. 114, Jan. 1926, 17 pp., 15 figs. Discusses tests of spray and brush painting; increased dues of spray painting, protection measures taken for spray painters in respirators.

Spraying Machines. Spray Painting by Textile Mills. Textile World, vol. 49, no. 1, Jan. 2, 1926, pp. 79–81. Design and operation of spray-painting machines and their advantages.

PAINTS

Coating Materials. Exposure Tests on Some Quick Drying Coating Materials, H. A. Gardner. Paint Manufacturers' Assn. of U. S., Sci. Section—Circular no. 251, Nov. 1925, pp. 150–167, 1 fig. Discusses roof exposure tests made in one coat work of black iron panels of a large variety of 203 different cuttings consisting of various oils, alcohols, benzols, gums, color, acetates, varnish, lampblack, etc.

White. The Reflecting Properties of White Interior Paints of Varying Compositions, A. L. Powell and R. B. Kellogg. Illum. Eng. Soc.—Trans., vol. 21 no. 1, Jan. 1926, pp. 70–82, 8 figs. Discusses deterioration in reflective power which white paint undergoes when subjected to light and industrial conditions; methods for obtaining reflection factors, and other requirements of paints.

PIGMENTS

Lithopone. Lithopone Making Rapid Progress in Plant Industry, C. F. Beatty. Chem. & Met. Eng., vol. 33, no. 1, Jan. 1926, pp. 27–28. Zinc pigments finding increasing outlets in rubber, plastics, printing inks, pottery glazes, abrasives and oil cloth.

PIPE, CAST-IRON

Bronze Welding. Effect of Heat of Bronze Welding on Cast Iron Pipe, A. R. Lytle. Am. Welding Soc.—Jl., vol. 5, no. 1, Jan. 1926, pp. 28–50, 35 figs. Discusses theories that depend on structural changes occurring in cast iron due to heat of application of bronze; cast-iron welding of sand-cast and centrifugally cast pipe; bronze welding of the same, etc.

Centrifugally Cast. Making Cast Iron Pipe Centrifugally, F. Grossmann. Foundry, vol. 54, no. 2, Jan. 15, 1926, pp. 58–59. Description of the de Lavaud machine and its operation; advantages of centrifugal process.

The Principles of Centrifugal Casting as Applied to the Manufacture of "Spun" Iron Pipes, E. J. Fox and P. H. Wilson. Foundry Trade Jl., vol. 33, nos. 491 and 492, Jan. 14 and 21, 1926, pp. 23–26 and 43–48, 21 figs., and (discussion), no. 493, Jan. 28, pp. 63–64. Considers principles governing de Lavaud process as manufactured at Stanton, also finished product, and tests to which it has been subjected; gives brief description of plant; summary of advantages of spun pipe; in author's belief, it is only question of time before process replaces older methods. See also editorial comment on p. 41, Jan. 21.

Quantity Production. Cast-Iron Pipes and Their Quantity Production for Water, Gas and Steam Piping (Ueber gusseiserne Rohre und ihre Massenherstellung für Wasser-, Gas- und Dampfleitungen), A. Schwarze. Zeit. für die gesamte Giessereipraxis, vol. 46, nos. 47 and 48, Nov. 22 and 29, 1925, pp. 541–543 and 549–550. Modern quantity production of pipes by means of rotary drum; preparation of sand; number and size of drums; number and location of cupolas; casting of blast-furnace iron, etc.

PNEUMATIC MACHINERY

Lubrication. Lubrication of Pneumatic Machinery. Lubrication, vol. 12, no. 1, Jan. 1926, 12 pp., 25 figs. Lubrication of air tools on pneumatic machinery; design, construction and operation of drills, riveters, hoists, their operating conditions, lubrication requirements, cleanliness and methods of cleaning.

POLISHING

Methods. Metal Polishing by Modern Methods, Machy. (N. Y.), vol. 32, no. 7, Mar. 1926, pp. 563–566, 9 figs. Polishing handle-bar brace and post, and circular grooves; wheels and operations for polishing wrenches and screw drivers; examples of brass finishing; cast-iron handles and wheels; finishing turbine buckets; polishing aluminum parts; special devices for polishing.

POWER

Developments, Mississippi Valley. Power Developments in the Mississippi Valley, S. Insull. Power Plant Eng., vol. 30, no. 4, Feb. 15, 1926, pp. 250–253. Resources of Middle West; development of interconnected power systems; power outlook for future.

Midwest Power Conference, Chicago. Midwest Power Conference Meets All Expectations. Power, vol. 63, no. 6, Feb. 9, 1926, pp. 211–218. Review of papers presented at conference held in Chicago from Jan. 26 to 29, 1926, discussing power developments in Mississippi Valley; water power and interconnection; changing viewpoints in turbine practice; combined operation of steam and hydraulic systems; electric-power development in Chicago district; by-product

processing; boiler-water conditioning; industrial-plant design; turbine testing; first aid and power for coal mines; oil and gas power; etc.

Power Show, Chicago. Chicago Power Show Arouses Great Interest. Power Plant Eng., vol. 30, no. 4, Feb. 15, 1926, pp. 282–294, 35 figs. Review of exhibits, including coal-burning equipment; boilers, superheaters and economizers; soot blowers; furnace construction; steam turbines and engines; condenser equipment; valves for steam water and oil; steam traps; coal and ash-handling machinery; electrical equipment; indicating and recording instruments. See also account in Power, vol. 63, no. 6, Feb. 9, 1926, pp. 218–224, 17 figs.

POWER TRANSMISSION

Mechanical, Control of. The Control of Mechanical Power Transmission, Wm. Staniar. Indus. Mgmt. (N. Y.), vol. 71, no. 2, Feb. 1926, pp. 89–92, 3 figs. General conclusions on economies of correct transmission.

Shafting. Using Steel Forms for Supporting Lineshafting, P. L. Pyribil. Indus. Engr., vol. 84, no. 1, Jan. 1926, pp. 19–25, 14 figs. Erection of lineshafts in mill-type steel and concrete buildings, with particular attention to provisions for easy anchorage of mechanical equipment and to facilitate future changes in layout.

PRESSES

Punch, Die Sets for. Standardized Die Sets for Punch-Press Work, F. H. Colvin. Am. Mach., vol. 64, no. 6, Feb. 11, 1926, pp. 245–249, 19 figs. How standardization of sets makes it possible to use modern production methods and to secure accurate results at low cost.

PRODUCER GAS

Hot and Cold. Evaluation of Hot and Cold Lignite and Coal Producer Gas (Die Bewertung von heissen und kalten Braunkohlen- und Steinkohlengeneratorgasen auf Grund der Bezugszahl), H. Becker. Braunkohle, vol. 24, no. 36, Dec. 5, 1925, pp. 793–799, 1 fig. Determines values and curves for hot and cold producer gases, and gives practical examples.

PROJECTILES

Spark Photography. Spark Photography Applied to Small Arms, P. P. Quayle. Army Ordnance, vol. 6, no. 34, Jan.-Feb. 1926, pp. 252–258, 14 figs. Problems of exterior ballistics of small arms, acceleration after leaving muzzle, gas leakage, sound-wave phenomena and gas motion at muzzle, shot shells, etc.

PULVERIZED COAL

Boiler Firing. A Critical Analysis of Pulverized Fuel for Small Boiler Plants, A. A. Fette. Nat. Engr., vol. 30, no. 2, Feb. 1926, pp. 65–67. Discussion of bin or storage system; drying of coal; problems of pulverized-coal plant; comparison with stokers; cost data of pulverizing and stoker systems.

Notes on Powdered Fuel, W. Lulofs. Elec. Times, vol. 69, no. 1787, Jan. 14, 1926, pp. 35–38, 3 figs. Discusses reduction of excessive air for combustion to limit supply to that which is theoretically necessary, and its consequent advantages in decreasing heat losses due to reduction of quantity of unnecessary air heated and saving of heat units because smaller quantity of gas can be reduced by boiler to a lower temperature before reaching the chimney.

Powdered Fuel, W. Lulofs. Combustion, vol. 14, no. 1, Jan. 1926, pp. 40–43, 1 fig. Discusses pulverized coal firing combined with mechanical stoking resulting in decreased efficiency and steam production and increased adaptability for varying load.

Pulverized Fuel Firing, E. Kilburn. Inst. Marine Engrs.—Trans., Jan. 1926, pp. 555–584, 15 figs. Discusses rapid growth; experiments of ships; superior combustion; maintenance of CO_2 and CO gases; Lopulco system of firing; fineness of grinding; construction of wall; size of furnace; Murray tubes, radiant superheater, beater pulverizers; describes Peterborough and Dover power stations.

Carbonization. Carbonization of Pulverized Fuel at Low Temperature, S. McEwen. Combustion, vol. 14, no. 2, Feb. 1926, pp. 107–110, 2 figs. McEwen-Rune process of pulverization of coal to be carbonized and its elevation to top of an internally heated tower; powdered fuel is caused to fall down this tower in form of a cloud meeting in its downward passage and upward current of hot inert gases.

Developments. Pulverized Coal, K. C. Barrell. Instn. Mech. Engrs.—Proc., no. 1, 1926, pp. 37–50, 5 figs. Author states that on continent and in America, pulverized coal is accepted fact for all heating purposes; in England it is only just being recognized as anything but a freak idea, and fuel users still exist who have never heard of it at all.

Gyro Gasification. Gyro Gasification. Iron & Coal Trades Rev., vol. 112, no. 3019, Jan. 8, 1926, pp. 58–59, 2 figs. Gyro system of pulverized-fuel firing recently introduced by Lindley, Duffield & Co., London, consisting of pulverizer which supplies direct what is described as a gasifier, which is circular or oval in section and takes place of usual furnace boiler; design of pulverizer is based on fact that coal has a disposition to fracture readily by impact.

Pulverisers. Classification of Pulverizers (Ein Beitrag zur Einteilung der Kohlenmühlen), K. Sperling. Feuerungstechnik, vol. 14, no. 6, Dec. 15, 1925, pp. 61–63. Discusses work of pulverizing, degree of fineness and its variation; types of pulverizers, percussion, centrifugal, roller, and drop mills; high speed and low speed.

PUMPS

Hydraulic. A New Hydraulic Pump. Engineer, vol. 141, no. 3654, Jan. 8, 1926, pp. 52–53, 1 fig. New design brought out by West Hydraulic Eng. Co.; it is of vertical type, and one of its outstanding features is provision made for lubricating running parts.

PUMPS, CENTRIFUGAL

Hydrodynamic Theory. The Hydrodynamic Theory of Turbines and Centrifugal Pumps, B. Eck. Engineering, vol. 121, nos. 3134 and 3135, Jan. 22 and 29, 1926, pp. 98–101 and 125–127, 21 figs. Author has succeeded in deducing exact solution for one particular case of turbine or pump problem, that in which turbine has but a single vane; from this he has derived approximate expressions applicable to practical turbines or centrifugals having multiple vanes.

PYROMETERS

Indicating and Recording. Indicating and Recording Pyrometers, P. M. Heldt. Automotive Industries, vol. 54, no. 3, Jan. 21, 1926, pp. 94–99, 9 figs. Their design and operation; potentiometer principle; automatic cold-junction compensation; checking against standard cell; automatic signaling device; automatic inking arrangement.

R

RADIATORS

Motor-Bus. New Radiator Developed for Six-Wheel Bus. Automotive Industries, vol. 54, no. 3, Jan. 21, 1926, p. 105. Radiator is fitted with re-flow tank which allows condensation of water and prevents water supply from becoming low in hot weather, and also prevents loss of anti-freeze mixture during winter operation.

RAILS

Failure. An Examination into the Causes of the Failure of Steel Rails, E. A. Dancaster. Ry. Engr., vol. 47, no. 552, Jan. 1926, pp. 21–27 and 33, 7 figs. Series of investigations into microstructure of rails which have failed in service, showing that in sound rails fracture is close to the end, generally passing through fishbolt holes; failure in flawed rail is due to pipes, transverse cracks, blowholes, or excessive segregation.

Specifications. Report of Committee on Rail. Am. Ry. Eng. Assn.—Bul., vol. 27, no. 283, Jan. 1926, pp. 473–629, 70 figs. Revised specifications for spring washers; rail failures; effect of various bolt tensions on mechanical strength of joints; effect of welding in changing structure of rail; standard specifications for manufacture of open hearth-steel girder rails of plain, grooved and guard types.

Transverse Fissures. Are Transverse Fissures in Rails Due to High Wheel Loads? Ry. Age, vol. 80, no. 4, Jan. 23, 1926, pp. 276–278. Railway engineers take exception to W. P. Borland's conclusion, expressed in letter published in same journal, Dec. 26, 1925.

Welding. Rail Welding for Nürnberg Railway Administration (Schieneschweisssungen bei der Reichsbahndirektion Nürnberg), Schönberger. Organ für die Fortschritte des Eisenbahnwesens, vol. 80, no. 22, Nov. 30, 1925, pp. 477–484, 12 figs. Tests made to determine behavior of a number of welded rails 84 and 108 m. in length; concludes that welding may possibly cut down maintenance cost (rail splices, etc.), 75 per cent, but admits that much more experimental work is necessary before such a conclusion is definitely justified.

RAILWAY ELECTRIFICATION

Factors Affecting. Factors Affecting Electrification, A. G. Oehler. Ry. Age, vol. 80, no. 1, Jan. 2, 1926, pp. 50–51, 1 fig. Points out that new conditions have been introduced which may influence future development.

RAILWAY MANAGEMENT

Accounting. Report of Records and Accounts. Am. Ry. Eng. Assn.—Bul., vol. 27, no. 281, Nov. 1925, pp. 245–284. Gathering and recording data for keeping up to date valuation records of property; feasibility of reducing number of forms, combining forms and simplifying those retained; comparison of daily and monthly time and material reports.

Forcasting Revenues. Forecastng Railway Revenues, J. E. Slater. Ry. Age, vol. 80, no. 2, Jan. 9, 1926, pp. 187–192, 11 figs. Methods worked out by New Haven to assist in budgeting of expenses.

Materials Accounting. Accounting for Materials and Supplies. Ry. Rev., vol. 78, no. 3, Jan. 16, 1926, pp. 165–167, 3 figs. Maintenance of accurate stock balances, proper reports of issue and annual inventories are essential. Reprinted from Dec. issue of N. C. & St. L. News Item.

RAILWAY MOTOR CARS

Gasoline-Electric. High Capacity Gas-Electric Car for the Seaboard. Ry. Age, vol. 80, no. 4, Jan. 23, 1926, pp. 273–275, 6 figs. Dual power plant and four motors permit high-speed operation with greater hauling capacity.

Brill-Westinghouse Build Rail Car with Gas-Electric Drive, P. M. Heldt. Automotive Industries, vol. 54, no. 6, Feb. 11, 1926, pp. 218–220, 2 figs. Six-cylinder engine designed by Brill and built by Westinghouse, develops 250 hp.; has dual valves and removable cylinder sleeves; starting, stopping and speed control effected through one lever.

The Reading Gas-Electric Rail Car, T. H. Murphy. Ry. Age, vol. 80, no. 2, Jan. 9, 1926, pp. 168–170, 4 figs. Car is controlled from either end and can also be used in multiple-unit operation. See also Ry. & Locomotive Eng., vol. 39, no. 1, Jan. 1926, pp. 17–19, 1 fig.

RAILWAY OPERATION

Statistical Data. Traffic, Earnings and Expenses, M. O. Lorenz. Ry. Rev., vol. 78, no. 1, Jan. 2, 1926, pp. 41–45, 2 figs. Résumé of comparative statistical data pertaining to railway operation.

Train Control. Train Control Progress in 1925, J. H. Dunn. Ry. Age, vol. 80, no. 1, Jan. 2, 1926, pp. 115–119. Twenty-four divisions completed under first order and two under second; Interstate Commerce Commission has made two final results.

RAILWAY REPAIR SHOPS

New England Railroads. Maintenance of Motive Power on New England Railroads, E. Sheldon. Am. Mach., vol. 64, no. 6, Feb. 11, 1926, pp. 239–242, 11 figs. Machining new cylinders; boring and turning cylinder bushings; cylinders repaired by welding; pistons and piston rods; "barometer" for indicating shop program.

RAILWAY SHOPS

Steel Cars. Pennsylvania Rebuilds Steel Cars at Enola, W. W. Baxter. Ry. Rev., vol. 78, no. 1, Jan. 2, 1926, pp. 52–56, 11 figs. Old equipment being overhauled in large shop where safety and efficiency predominate.

RAILWAY SIGNALING

A. R. A. Report. Report on Signals and Interlocking. Am. Ry. Eng. Assn.—Bul., vol. 27, no. 281, Nov. 1925, pp. 315–351, 1 fig. Automatic train control; signals for highway-crossing protection; requisites for automatic signals for highway crossing protection.

Automatic Equipment, 1925. An Active Year in Interlocking and Signal Construction, J. H. Dunn. Ry. Age, vol. 80, no. 1, Jan. 2, 1926, pp. 97–104, 3 figs. More equipment placed in service during 1925 than in any year since 1914; statistical data on automatic signaling completed in 1925 and contemplated for 1926.

Colored-Light Signals. Automatic Signals Constructed in Record Time on Seaboard. Ry. Age, vol. 80, no. 5, Jan. 30, 1926, pp. 323–326, 6 figs. Contractor installs 254 miles of color lights on single track in 150 working days.

RAILWAY TIES

Preservative Treatment. Systematic Protection of Ties Effect Marked Economies, E. F. Robinson. Ry. Age, vol. 80, no. 2, Jan. 9, 1926, pp. 175–180, 3 figs.; also Ry. Eng. & Maintenance, vol. 22, no. 1, Jan. 1926, pp. 15–21, 4 figs. Timber-preserving plant at Bradford, Pa., of Buffalo, Rochester & Pittsburgh Ry.; methods employed; air seasoning; native hardwoods prove most satisfactory.

Specifications. Report of Committee on Ties, Am. Ry. Eng. Assn.—Bul., vol. 27, no. 283, Jan. 1926, pp. 687–732, 9 figs. Specifications for cross-ties, switch-ties, dating nails; making ties for service records; extension of service test records for furnishing information for study of economics of ties; adherence to specifications; substitute ties.

RAILWAY TRACK

Crossings. Can the Highway be Made Safe at the Railway Crossing? A. H. Blanchard. Good Roads, vol. 68, no. 11, Dec. 1925, pp. 303–305 and 320. Discusses mechanical traffic control methods to promote safety, elimination of grade crossings, or increased protection; warnings at all crossings; full-stop law; protection at night, etc.

Report of Signs, Fences and Crossings. Am. Ry. Eng. Assn.—Bul. vol. 27, no. 282, Dec. 1925, pp. 389–434, 22 figs. Apportioning cost of highway improvements adjacent to railways; elimination of highway grade crossings; preventing corrosion of fence wire, etc.

Curves. Wheelbase, Wheel Diameter, and form of Wheel Flange, in Relation to Width of Grooves and Flanges in Track Curves (Die Beziehungen von Radstand, Raddurchmesser und Spurkranzform zu Rillen- und Spurweite bei Gleiskrümmungen), Thomas. Verkehrstechnik, no. 52, Dec. 25, 1925, pp. 1000–1003, 4 figs. Calculation of width of flange in curves for a given flange and standard wheelbases, and derives a flange running through smallest admissible curves without cutting rails.

Maintenance. Economic Track Maintenance by Using Tamping Process (Wirtschaflichere Gestaltung der Bahnunterhaltung durch Anwendung des Stampfverfahrens), Faatz. Organ für die Fortschritte des Eisenbahwesens, vol. 80 no. 22, Nov. 30, 1925, pp. 484–493, 11 figs. Determination of economic thickness of ballast for new axle and wheel pressures, and method of tamping; relation between thickness of ballast and load; cost of maintenance.

Reinforced-Concrete Slab. Building a More Permanent Track, F. H. Alfred and P. Chipman. Ry. Eng. & Maintenance, vol. 22, no. 1, Jan. 1926, pp. 4–8, 4 figs. Reinforced-concrete slab is suggested to support rails; marked savings anticipated.

Relaying Machines. Railway Track-Relaying Machine. Engineering, vol. 121, no. 3134, Jan. 22, 1926, pp. 102–103, 24 figs. partly on supp. plates. Machine designed and patented by A. W. Bretland, is adaptation to track laying, of system of block laying, long standardized in pier and harbor work. See also description in Engineer, vol. 141, no. 3655, Jan. 15, 1926, pp. 75–77, 9 figs.

Specifications. Report of Committee on Track. Am. Ry. Eng. Assn.—Bul., vol. 27, no. 283, Jan. 1926, pp. 631–686, 25 figs. Proposed revised specifications for steel tie plates and for soft-steel track spikes; specifications for grog filler sections and for wooden handles for track tools; effect of brine drippings on track appliances; canting rail inward and taper of tread of wheel; railway renewals; tie plates, etc.

RAILWAY YARDS

A. R. A. Report. Report of Committee on Yards and Terminals. Am. Ry. Eng. Assn.—Bul., vol. 27, no. 282, Dec. 1925, pp. 353–388, 6 figs. Joint use and

operation of passenger terminals; scales; freight-yard design; mechanical means for controlling movement of cars in hump yards.

Car Classification. Mechanical Classifying of Freight Cars. Compressed Air Mag., vol. 31, no. 1, Jan. 1926, pp. 1511–1513, 7 figs. Electropneumatic systems for speeding up work, Hannauer car retarder; electropneumatic skate thrower by the Union Switch & Signal Co.

REDUCTION GEARS

Types. Gears for Speed Reduction. Power, vol. 63, no. 5, Feb. 2, 1926, pp. 181–183, 8 figs. Types of gear drives; applications in power plant.

REFRACTORIES

Properties. Refractories, M. C. Booze. Fuels & Furnaces, vol. 4, no. 1, Jan. 1926, pp. 41–44 and 71–72. Discusses consumption, life, selection and testing of refractories; improvement of properties, recent developments.

REFRIGERATING MACHINES

Ammonia-Evaporation System. A New Refrigerator. Engineer, vol. 141, no. 3660, Feb. 19, 1926, pp. 220–221, 6 figs. Machine invented by two Swedish engineers, B. de Platen and C. Munters, which works on ammonia-evaporation principle and is continuous in its action; it embodies no moving elements whatsoever, no motor, fan, valve nor other mechanical operating device forming part of its construction.

High-Speed. Modern High Speed Refrigerating Machines, G. W. Daniels. Cold Storage, vol. 29, no. 334, Jan. 21, 1926, pp. 9–12. Advantages and disadvantages of low speed and high speed; construction of valves, suction pipes and passages, lubrication, balancing, etc.

Lubrication. Lubrication of Refrigerating Machinery, A. F. Brewer. Power Plant Eng., vol. 30, no. 3, Feb. 1, 1926, pp. 220–222. Effects of lubricants on parts not requiring lubrication, as well as their effects on actual wearing parts, must be considered.

Modern Oiling Devices for Inclosed Refrigerating Machines, T. Mitchell. Power, vol. 63, no. 6, Feb. 9, 1926, pp. 209–210, 4 figs. Limitation of splash system; oiling by inertia; pressure feed systems.

REFRIGERATING PLANTS

Corrosion. Corrosion in the Refrigerating Industry, W. G. Whitman, E. L. Chappell and J. K. Roberts. Ice & Refrigeration, vol. 70, no. 1, Jan. 1926, pp. 46–51, 11 figs. Reports submitted to committee on corrosion of Am. Soc. of Refrig. Engrs., covering general principles of corrosion, corrosion in condenser systems and in brine systems. Bibliography.

Efficiency. Limits of Refrigerating Plant Efficiency, V. J. Azbe. Ice & Refrigeration, vol. 70, no. 1, Jan. 1926, pp. 33–40, 8 figs. Also Power, vol. 63, no. 4, Jan. 26, 1926, pp. 138–139, 4 figs. Discusses that part where power is applied to compress ammonia to produce refrigeration and factors which determine range through which ammonia is to be compressed.

Heat Balance. Heat-Balance in a Refrigerating Plant, W. S. Huntington. Refrigeration, vol. 38, no. 1, Jan. 1926, pp. 44–46, 2 figs. Attempts to construct a heat-balance diagram; discusses freezing tank, tank insulation, daily storage, ratio of refrigeration and ice tonnage, distribution of refrigerating cost in cents per dollar expended.

Heat Leakage. Heat Leakage in the Refrigerating Plant, W. H. Huntington. Power, vol. 63, no. 3, Jan. 19, 1926, pp. 96–97, 1 fig. Chart showing leakage from bare and insulated tanks; permits calculation for most efficient thickness of covering.

Insulation. The Insulation of Cold Stores. Ice & Cold Storage, vol. 29, no. 334, Jan. 1926, pp. 3–5, 4 figs. Discusses question of insulation of refrigerating installations as affecting machinery, piping and buildings, and gives results of experiments and experience. Translated from Sulzer Tech. Rev.

REFRIGERATION

Ottesen Process. French Opinion of the Ottesen Process, W. W. O'Mahoney. Ice & Cold Storage, vol. 29, no. 334, Jan. 1926, pp. 7–8. Discusses favorable experience with this process in which chilled brine is transformed into a liquid absolutely neutral from the osmotic standpoint, preventing salt from getting into tissues.

RESEARCH

Industrial. The Administration of Industrial Research, E. R. Weidlein. Indus. & Eng. Chem., vol. 18, no. 1, Jan. 1926, pp. 98–101. General absence of scientific research methods in chemical technology led to formulation in 1906 of Indus. Fellowship System of Mellon Inst.; review of gradual development; scope of research management; definition of research organization; principles of research laboratory management; functions of organization; selection of research men.

Value to Industry. Kansas City Meeting of the A.A.A.S. Mech. Eng., vol. 48, no. 2, Feb. 1926, pp. 179–185. Review of papers presented before Am. Assn. for Advancement of Science, as follows: Motive and Obligation, F. B. Jewett, discussing engineering, industrial research, research without utilitarian objective, and interdependence of fields to which they pertain; Research—the Prime Mover of Industry, M. Holland; the Frontiers of Industry, E. P. Stevenson; Administration of Industrial Research, E. R. Weidlein; Evaluating Research Ideas, F. O. Clements; Coöperation between Industry and University, G. D. McLaughlin.

ROLLING MILLS

Continuous. Ford Merchant Mill in Operation. Iron Age, vol. 117, no. 3, Jan. 21, 1926, pp. 197–201, 3 figs. First unit of new steel works is 14-in. motor-driven continuous mill; unusual features.

ROLLS

Engraved Steel and Copper. Making Engraved Rolls of Steel and Copper. Am. Mach., vol. 64, nos. 2 and 4, Jan. 14 and 28, 1926, pp. 57–60 and 163–167, 19 figs. Jan. 14: preliminary steps taken to produce upon steel and copper rolls designs that are later to be transferred by them to metal, cloth or paper. Jan. 28: Methods employed to engrave designs upon copper cylinders of textile printing machines.

S

SAND, MOLDING

Steel. Steel Moulding Sands and Their Behavior Under High Temperature, A. L. Curtis. Engineering, vol. 121, nos. 3137 and 3138, Feb. 12 and 19, 1926, pp. 216–218 and 248–249, 10 figs. Natural argillaceous sands; refractory qualities of English steel molding sands; method adopted and apparatus used for testing sands under high temperature. (Abridged.) Carnegie Scholarship Memoir read before Iron and Steel Inst.

SCREW MACHINES

Automatic. Rapid Production in Automatics, W. S. Davenport. Machy. (N. Y.), vol. 32, no. 6, Feb. 1926, pp. 456–461, 5 figs. Typical examples of work performed in small-size multiple-spindle automatic screw machines.

SEAPLANES

Radio Equipment. The Wireless Equipment of a Seaplane. Engineer, vol. 141, no. 3660, Feb. 19, 1926, p. 209, 2 figs. Use of wireless apparatus installed on Dornier seaplane, Ne Plus Ultra.

See also FLYING BOATS.

SHAFTS

Critical Speeds. Determination of Critical Angular Velocity (La Détermination des Vitesses angulaires critiques), F. H. Van den Dugen. Assn. des Ingénieurs de l'École Polytechnique de Bruxelles—Bul. Technique, vol. 21, no. 1, 1925, pp. 1–15, 3 figs. Discusses formulation of integral equation, phenomenon of resonance, various methods of calculation, and examples: physical properties of critical speed, stabilizing speeds; problems with several parameters.

Diagrams. Shaft Diagrams, J. R. Hurford. Power, vol. 63, no. 2, Jan. 12, 1926, pp. 59–61, 5 figs. Presents charts constructed by author to solve formula proposed by A. L. Jenkins for shaft made of ductile material.

SHAPERS

Rack-Cutting Attachment. Rack-Cutting Attachment for Shaper, A. L. Greene. Machy. (N. Y.), vol. 32, no. 7, Mar. 1926, p. 527. Adaptation of ordinary shaper to rack-cutting purposes; made in plant of E. & B. Holmes Machy. Co., Buffalo, N. Y.

SHEET METAL

Rolling Sections. Rolling Sheet-metal Sections. Machy. (N. Y.), vol. 32, no. 7, Mar. 1926, pp. 556–559, 8 figs. Cold-forming sheet-metal sections to any length by use of machines equipped with multiple rolls.

SMOKE

Abatement. Smoke Reduction with Economy, C. V. Beck. Black Diamond, vol. 76, no. 1, Jan. 2, 1926, pp. 6–7 and 12, 4 figs. Discusses increased efficiency by smoke reduction, proper size of coal, firing instructions, etc.

SOLIDS

Heat Conductivity. Heat Conductivity of Solids at Low Temperature (Die Wärmeleitfähigkeit fester Körper bei tiefen Temperaturen), A. Eucken. Zeit. für technische Physik, no. 12, 1925, pp. 689–694, 2 figs. Discusses results of measurements on non-metallic solids; Debye's theory of heat conductivity; recent results in field of heat conductivity of metals.

SPRINGS

Ring. The Ring Spring, O. R. Wikander. Mech. Eng., vol. 48, no. 2, Feb. 1926, pp. 139–143, 8 figs. Characteristics and advantages of type of compression spring consisting of assembly of alternate inner and outer rings, each coating with adjacent ones along conical surfaces; design formulas and illustrative calculation.

STEAM

Charts and Tables. Progress Report on the Development of Steam Charts and Tables from the Harvard Throttling Experiments, J. H. Keenan. Mech. Eng., vol. 48, no. 2, Feb. 1926, pp. 144–151, 9 figs. partly on supp. plate. Presents new steam chart and tables based on Harvard throttling experiments which reach pressures as high as 565 lb. per sq. in. absolute and temperatures in neighborhood of 600 deg. fahr.; data for temperatures below 320 deg. fahr.—temperatures not covered by new Joule-Thomson experiments—are obtained from Marks and Davis steam tables; development of Harvard data involved use of Knoblauch specific-heat determinations.

High-Pressure. Thermal Properties of High-Pressure Steam (Die thermischen Eigenschaften des hochgespannten Wasserdampfes), O. Knoblauch. Zeit. für technische Physik, no. 12, 1925, pp. 638–644, 3 figs. Thermodynamic application of steam tables based on experimental determination of specific heat; construction of steam tables and curves.

Pressure Regulators. Steam Pressure Regulators (Dampfdruckregler), W. Riedel. Wärme, vol. 48, no. 42, Oct. 16, 1925, pp. 529–532, 6 figs. Design and construction of high-pressure reducing valves, live-steam valves, exhaust-steam regulators for medium pressures.

Research. Progress in Steam Research. Mech. Eng., vol. 48, no. 2, Feb. 1926, pp. 151–160, 19 figs. Reports presented at session on Progress in Steam Table Research, Dec. 2, 1925, as follows: Report of Executive Committee of Steam Table Fund; Report on Progress in Steam Research at the Bureau of Standards, N. S. Osborne and H. F. Stimson; Report on Progress in Steam Research at Massachusetts Institute of Technology, L. B. Smith; Notes on Steam-Research Work Carried out at Harvard University, R. V. Kleinschmidt; Temperature Scale and Pressure Standard Employed in M.I.T. Steam-Research Measurements, F. G. Keyes; Progress Made in Technique of Computing a Steam Table from the Harvard Data, H. N. Davis; Comparison with the Formulations, R. C. H. Heck. These reports are supplementary to those published in same journal, Feb. 1924 and Feb. 1925.

STEAM ACCUMULATORS

Development. Development of Steam Accumulators and Their Use (Die Entwicklung der Dampfspeicher und deren Verwendung), H. E. Witz. Elektrotechnische Zeit., vol. 46, nos. 48 and 49, Nov. 26 and Dec. 3, 1925, pp. 1797–1800 and 1844–1848, 26 figs. Development and design of types of accumulators for hot water and steam by MacMahon, Rateau, Ruths, Halpin, Kouznezoff and Christians. Examples of Ruths accumulator plants at various factories.

Ruths. Ruths Steam Accumulators (L'accumulateur de vapeur Ruths), H. Schrenk. Revue Universelle des Mines, vol. 8, no. 6, Dec. 15, 1925, pp. 347–361, 16 figs. Details of examples of applications in coal mines, central stations, and metallurgical works.

STEAM ENGINES

Development. Conversion of Reciprocating Steam Engines to Combined Steam and Internal Combustion Engines. Diesel & Oil Engine Jl., vol. 2, no. 1, Jan. 1926, pp. 13–18, 6 figs. Discusses invention by Cox and Lagergreen with the object of improving economy of the old steam power plant of ship and to provide the vessel with such power as to make it independent as to the kind of fuel at the ports of call, giving a cost ratio of 1 to 5 in favor of the converted engine.

STEAM POWER PLANTS

Back-Pressure Operation. Successes with Back-Pressure Operation and Its Application in Long-Distance Service (Ueber Erfolge mit Gegendruckbetrieben und ihre Heranziehung zur Ueberlandversorgung), Uihlein. Wärme, vol. 48, no. 50, Dec. 11, 1925, pp. 629–634, 8 figs. Discusses economic efficiency, taking actual and projected plants in the chemical, textile and paper industries as examples; surplus energy, and the use in factories as well as in central stations, and methods of determining surplus energy to be expected.

Hotels. Steam and Electric Service in Detroit's Largest Hotel. Power, vol. 63, no. 3, Jan. 19, 1926, pp. 86–90, 4 figs. In Book-Cadillac Hotel, boilers were installed to supply heat, electrical energy was purchased and for various services both steam and motor-driven machines were provided, so that exhaust would be available in winter and motor-driven machines used in summer; data on pincipal equipment of power plant. See also description by E. A. Sitter and S. L. Potts, in Nat. Engr., vol. 30, no. 1, Jan. 1926, pp. 1–8, 4 figs.

The Belvedere Starts Its Power Plant Again, H. E. Nelson. Power, vol. 63, no. 6, Feb. 9, 1926, pp. 204–205, 1 fig. Baltimore's leading hotel finds it can generate energy cheaper than it can be purchased; uniflow cylinders installed on single-valve engines reduce steam consumption; motor-driven pumps replace steam-driven units to provide better heat balance.

Piping Design. Modeling as an Aid in Power-Plant Piping Design, C. T. Van Dusen. Power, vol. 63, no. 8, Feb. 23, 1926, pp. 282–283, 3 figs. Conducted as part of, and simultaneously with drafting-room work, modeling proves to be of great value in design of power-plant piping.

Research. Bureau of Mines Aids Power Plant Practice. Power Plant Eng., vol. 30, no. 4, Feb. 15, 1926, pp. 246–249, 7 figs. U. S. Government station at Pittsburgh conducts intensive research in combustion, feedwater treatment and refractory problems.

Stand-by Stations. Recent Refinements in Power-plant Auxiliary Apparatus and Operating Methods. Southern Power Jl., vol. 44, no. 1, Jan. 1926, pp. 1–10, 13 figs. Discusses stand-by steam stations of various electric power plants for generating electric energy during summer and method of operation.

STEAM TURBINES

Efficiency. The Potential Efficiency of Prime Movers, C. V. Kerr. Power, vol. 63, no. 8, Feb. 23, 1926, pp. 297–298. Points out that efficiency of steam turbines should be figured on basis of available energy in steam over given range from throttle to exhaust; on this basis, steam engine and turbine make fairly good showing.

Efficiency Calculation. Effect of Load Variations on Efficiency of Steam-Turbine Plants (Ueber den Einfluss der Belastungsschwankungen auf den Wirkungsgrad von Dampfturbinenanlagen), Melan. Siemens Zeit., vol. 5, no. 11, Nov. 1925, pp. 485–492, 14 figs. Shows that calculation of turbines on average load and quantity of steam is only applicable strictly to turbines showing linear and constant relation of performance to quantity of steam.

Industrial Plants. Adapting the Steam Turbine to the Industrial Power and Heating Load, C. S. Coggeshall. Power, vol. 63, no. 9, Mar. 2, 1926, pp. 329–332, 3 figs. Discusses diversified demands of industrial plant and describes line of turbines which, like sectional filing cabinets, can be set up to meet almost any requirements.

Small. A New Line of Small Turbines, R. R.

Lewis. Power, vol. 63, no. 5, Feb. 2, 1926, pp. 178–180, 4 figs. Describes series of small turbines developed by Gen. Elec. Co. to meet demand for small units of refined design.

STEEL

Automobile. S.A.E. Steels. Am. Mach., vol. 64, no. 7, Feb. 18, 1926, p. 291. Reference-book sheet on chemical composition of steels for automotive parts.

Bending Stresses, Effect of. Safe Loads and Endurance of Steels under Repeated Bending Stresses. Engineer, vol. 141, no. 3657, Jan. 29, 1926, p. 130. Review of article by V. Prever and E. Balma, published in Ingegneria, giving results of number of alternating bending-stress tests on series of 42 steels comprising wide range of compositions and including several nickel and nickel-chromium-tungsten steels with varying carbon contents; authors conclude that safe loads and relative coefficients now in use represent nothing of any mathematical certainty, and are of no more than a conventional character; it is proved that practical limits of fatigue are lower in proportion as number of minimum loadings increases; medium stresses repeated with great frequency may prove just as dangerous as much higher stresses of lower frequency or shorter duration.

Hardening and Tempering. Hardening and Tempering Steels, P. Nicolau. Iron Age, vol. 117, no. 6, Feb. 11, 1926, pp. 403 and 458–459, 3 figs. Effect on thermoelectric electromotive force; method used in French tests; value in tool-steel hardening. Translated from Revue de Métallurgie, vol. 22, Aug. 1925.

High Temperatures, Effect of. Behavior of Steel at Elevated Temperatures, O. A. Knight. Forging—Stamping—Heat Treating, vol. 12, no. 1, Jan. 1926, pp. 36–40. Comprehensive report covering behavior of cold-drawn mild steel at elevated temperatures; experiments discussed were confined to tensile tests.

Superheating. Superheating of Steels (Etude sur la surchauffe des aciers), L. Aisenstein and E. Decherf. Revue Universelle des Mines, vol. 8, no. 6, Dec. 15, 1925, pp. 330–346, 36 figs. Discusses carbon, nickel and chrome-nickel steels and effect of superheating on mechanical properties; resistance to tension, elastic limit, elongation, contraction of area, resiliency; study of structure.

Thermal Transformation. Experimental Apparatus for Demonstrating Thermal Transformations of Steels and Anomalies of Special Alloys (Appareils de tours pour mettre en evidence les transformations chermiques des aciers et les anomalies des alliages speciaux), P. Chevenard. Jl. Physique & Radium, vol. 6, no. 8, Aug. 1925, pp. 264–272, 12 figs. Apparatus for demonstrating recalescence of high-carbon steels; for drawing dilatometric curves of alloys; a thermomagnetic recorder for magnetization temperature curves; a thermoelastic oscillometer and twisted thread galvanoscope to show thermoelastic anomaly of certain reversible ferronickels.

STEEL CASTINGS

Electric. Discussion on Mr. Melmoth's Paper on "Some Metallurgical Points on Electric Steel Castings and Notes on Defects." Foundry Trade Jl., vol. 33, no. 490, Jan. 7, 1926, pp. 13–15. Discusses contraction in wheel castings; liquid contraction; actual contraction determined; cost of electric steel castings; fluidity and light emission; shape of risers.

STEEL, HIGH-SPEED

Manufacture. Making High Grade Steel, J. A. Coyle. Iron Trade Rev., vol. 78, nos. 4 and 6, Jan. 28, and Feb. 11, 1926, pp. 261 and 268–269, 3 figs., and 397–399, 1 fig. Jan. 28: Production of high-speed steel, and difficulties met with; chemical analyses of typical tool steels. Feb. 11: History of heat, with full information on analyses, practice, etc.

STEEL INDUSTRY

Annual Analysis, 1925. Fifth Annual Analysis Shows Steel's Use. Iron Trade Rev., vol. 78, no. 1, Jan. 7, 1926, pp. 11–14, 5 figs. Presents annual analysis for 1925 of finished steel among leading consuming groups; various aspects of year's business in analysis of shipments and consumption in accordance with classified groups; gross production of finished steel in United States in 1925 approximates 33,000,000 tons, greatest ever recorded; steel requirements of automotive industry contributed more than any other single element to building up of great market.

STEEL WORKS

Andrews Co., Kentucky. Genuine Open-Hearth Iron, F. J. Crolius. Blast Furnace & Steel Plant, vol. 14, no. 1, Jan. 1926, pp. 25–36 and 48, 10 figs. Plants, equipment and methods of Andrews Steel and Newport Rolling Mill Co.

Bethlehem Steel Works. Modernization at Bethlehem's Lackawanna Steel Works. Iron Age, vol. 117, nos. 1 and 6, Jan. 7 and Feb. 11, 1926, pp. 40–45 and 404–410, 25 figs. New coke ovens, blowing engines, two structural mills and scrap plant, rebuilt open-hearth furnaces and blooming mill; extensive electrification.

Mechanical Equipment. The Mechanical Equipment of Iron and Steel Works (Die maschinellen Einrichtungen der Eisenhüttenwerke), H. Hoff. Zeit. des Vereines deutscher Ingenieure, vol. 69, no. 31, Aug. 1, 1925, pp. 1013–1022, 22 figs. Charging equipment for blast furnaces; loading and unloading equipment for coke ovens; cleaning of coke-over gas; locomotives and railway cars; tipping arrangements of pig-iron mixers; hoists for steel and rolling mills; power plants.

STREET RAILWAYS

Cars. Attractive Cars Put Buffalo & Erie Railway on Paying Basis. Elec. Ry. Jl., vol. 67, no. 2, Jan. 9, 1926, pp. 58–64, 8 figs. Details of light-weight cars designed to give utmost service and attraction to passengers while at same time making substantial reductions in operating costs.

Unifying the Transportation Features of Toronto Rolling Stock. Elec. Ry. Jl., vol. 67, no. 3, Jan. 16, 1926, pp. 98–102, 6 figs. Discusses remodeling of cars for front-entrance operation, equipment with automatic rear exits, light and mirrors to insure safety to passenger movement.

SUN POWER

Machines. Sun-Power Machines (Sonnenkraftmaschinen), A. Remshardt. Zeit. des Vereines deutscher Ingenieure, vol. 70, no. 5, Jan. 30, 1926, pp. 159–162, 8 figs. Historical review; conversion of sun rays into energy; requirements of a sun-power machine, and details of a design based thereon.

SUPERHEATED STEAM

Properties. Superheated Steam and Superheaters (Der überhitzte Dampf and die Ueberhitzer), P. Wiegleb. Wärme, vol. 48, no. 52, Dec. 25, 1925, pp. 655–659, 4 figs. Properties of superheated steam, ist industrial applications and savings effected; mechanism of superheating; design and arrangement of superheaters; Babcock & Wilcox types.

SUPERHEATERS

Principle of. Getting Added Power from Waste Heat, F. Juraschek. Indus. Mgmt. (N. Y.), vol. 71, no. 1, Jan. 1926, pp. 55–59, 5 figs. Discusses use of superheaters.

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TEMPERATURE MEASUREMENT

Red-Hot Iron. Measuring Temperature of Red-Hot Iron (Temperaturmessungen an glühendem Eisen), M. Moeller, H. Niething and H. Schmick. Zeit. für technische Physik, no. 12, 1925, pp. 644–651, 8 figs. Gives corrective values of temperatures for surface radiation of red-hot, pure and oxidized iron, measured by means of an incandescent filament pyrometer and an ardometer.

TERMINALS, RAILWAY

St. Paul, Minn. The Saint Paul Union Depot, G. H. Wilsey. Minn. Federation Architectural & Eng. Soc.—Bul., vol. 11, no. 1, Jan. 1926, pp. 11–50, 17 figs. Design and construction of new Union Station, electrical and mechanical equipment, platforms, trains shed and tracks, elevators and ramps, subways, engine terminals, machine shops, etc.

TESTING MACHINES

Universal Horizontal. Universal Horizontal Testing Machine. Engineering, vol. 121, no. 3133, Jan. 15, 1926, pp. 85–86, 3 figs. Details of 100-ton machine made by A. J. Amsler & Co., Schaffhausen, Switzerland, designed for making tensile, compression and transverse bending tests.

TEXTILE MILLS

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Z

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